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Operation of the Computer Model for Microenvironment Atomic Oxygen Exposure

R. J. Bourassa, J. R. Gillis, and P. E. Gruenbaum
Boeing Defense & Space Group, Seattle, Washington

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OPERATION OF THE COMPUTER MODEL FOR MICROENVIRONMENT ATOMIC OXYGEN EXPOSURE

R. J. Bourassa
J. R. Gillis
P. E. Gruenbaum

For SHADOWV2

BOEING DEFENSE & SPACE GROUP

OPERATION OF SHADOWV2, THE COMPUTER MODEL FOR MICROENVIRONMENT ATOMIC OXYGEN EXPOSURE

FOREWORD

This report describes the operation of the computer model SHADOWV2, which was developed to predict atomic oxygen exposure to satellite surfaces which may shadow or reflect on one another. Boeing Defense & Space Group's activities were supported by the following NASA Langley Research Center (LaRC) contracts: "LDEF Special Investigation Group Support" contracts NAS1-18224, Tasks 12 and 15 (October 1989 through January 1991), NAS1-19247 Tasks 1 & 2 (May 1991 through October 1992), and NAS1-19247 Task 8 (initiated October 1992). Sponsorship for these programs was provided by National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, and The Strategic Defense Initiative Organization, Key Technologies Office, Washington, D.C.

Mr. Lou Teichman, NASA LaRC, was the initial NASA Task Technical Monitor. Following Mr. Teichman's retirement, Ms. Joan Funk, NASA LaRC, became the Task Technical Monitor. The Materials & Processes Technology organization of the Boeing Defense & Space Group performed the five contract tasks with the following Boeing personnel providing critical support throughout the program:

Sylvester Hill	Task Manager
Roger Bourassa	Modeling
Dr. James R. Gillis	Scientific Computing
Dr. Peter Gruenbaum	User Interface Programming
Dr. Gary Pippin	Project Coordination

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The microenvironment atomic oxygen exposure code SHADOWV2 has been changed from SHADOW version 1.1 (January 26, 1994) in the following significant regards. SHADOWV2 automatically calculates the visibility matrix, relieving the user of this task. Several improvements to program efficiency have been made which speed up computations. The algorithm for scattered (reflected) atomic oxygen has been revised to correct errors in SHADOW version 1.1 in the distribution of flux scattered onto surfaces. These changes have resulted in the addition of 14 new functions and subroutines in SHADOWV2 in addition to numerous changes in routines used in SHADOW version 1.1.

Input files for SHADOWV2 are the same as those for SHADOW version 1.1 with the following exceptions: The inputs for the visibility matrix (records C_i in SHADOW version 1.1) have been deleted. An additional variable, INACT, has been added at the end of record C3 (formerly record D3 in SHADOW version 1.1) to control output indicating which surfaces can see the inactive sides of surfaces during the automatic visibility matrix generation.

Output files for SHADOWV2 are very similar to those from SHADOW version 1.1. In particular, the format of the TECPLOT file, TAPE7, is identical between the two codes.

The interactive input file builder MDDB version 2.0 has been extensively changed from MDDB version 1.0. MDDB version 2.0 allows users to build and edit input files for microenvironment atomic oxygen exposure codes SHADOW version 1.1 and SHADOWV2 and for microenvironment solar exposure code SOLSHAD and to convert any one of these input files to any of the others. Editing input files has been made more user friendly.

The program to average values from the FLUXAVG mission file, AVESHAD 2.0, has changed from version 1.0 only in that it now reads and creates SHADOWV2 input files instead of SHADOW version 1.1 input files.

This document, while retaining the form of the SHADOW version 1.1 document, has been rewritten to reflect the changes in SHADOWV2 and MDDB.

GLOSSARY OF COMPUTER PROGRAMS

AVESHAD	Calculation of averaged atomic oxygen values
FLUXAVG	Direct atomic oxygen exposure model
FLUXPLOT	Extraction of data from FLUXAVG mission file
PREPLOT	Program to prepare data for commercial program TECPLOT
MDDB	Microenvironment input file builder (Microenvironment Data Deck Builder)
SHADOW	Microenvironment atomic oxygen exposure model
SHADOWV2	Version 2 of the microenvironment atomic oxygen exposure model
SOLSHAD	Microenvironment solar exposure model
TECPLOT	Commercial plotting program

1.0 INTRODUCTION

1.1 BACKGROUND

A computer model for atomic oxygen exposure of flat external surfaces of an Earth satellite is described in references 1. The referenced model is termed the direct atomic oxygen exposure model. This model accounts for satellite altitude, the fixed orientation of surfaces with respect to the direction of satellite motion through the atmosphere, and the effects of solar and geomagnetic activity on atmospheric conditions. The calculation is valid for any orbital path or duration of exposure and accounts for an osculating elliptical or circular orbit about an accurately modeled Earth. However, the model does not treat the effects of shadowing of one surface by another interfering surface or reflection of atomic oxygen between exposed surfaces. These latter effects are important in the design of satellite hardware and in interpretation of results from orbital tests of materials.

The computer model for microenvironment atomic oxygen exposure (ref. 2), has been developed to extend atomic oxygen modeling capability to include shadowing and reflections. This model uses average exposure conditions established by the direct exposure model and extends the application of these conditions to treat surfaces of arbitrary shape and orientation. The model comprises a suite of computer programs: SHADOW version 1.1, which calculates the flux to atomic oxygen microenvironment fluxes; MDDB, which allows the user to build and display input geometries for SHADOW interactively; and AVESHAD, which calculates the average atomic oxygen exposure to unshielded surfaces. Since the publication of that model, several improvements have been made to it. SHADOW version 1.1 has been upgraded to SHADOWV2. SHADOWV2 features improved calculational efficiency and more accurate handling of reflected atomic oxygen fluxes, and automatically calculates the visibility matrix, relieving the user of this task. (The visibility matrix is a matrix that notes which surfaces can be seen by other surfaces.) MDDB version 2.0 not only allows the user to create SHADOW version 1.1 input files, but also allows the user to create SHADOWV2 input files and SOLSHAD (ref. 3) input files, as well as to convert an input file for one program to any of the others. The application of version 2.0 of the computer model for microenvironment atomic oxygen exposure is described in this document.

1.2 OBJECTIVE

This report describes the technical features of the Computer Model for Microenvironment Atomic Oxygen Exposure Version 2.0 and provides directions for its operation.

1.3 SCOPE

Precise treatment of atomic oxygen reflections requires data on molecular reflectance and recombination efficiency properties of materials used in satellite design. At the present time very little data on these properties are available. Thus, application of the microenvironments model will depend on research activities to develop the required surface property data. The supporting research is not described in this report. Also, as formulated, the model calculates flux as the sum of all atomic oxygen reaching nodal points on a surface without distinction as to the kinetic energy distribution of the incident molecules. The energy distribution histogram can be developed within the framework of the model; however, the routines for this purpose have not been incorporated to date.

Even with the limitations noted, application of the microenvironments model has been made to evaluate on-orbit materials test results using estimated surface properties (refs. 4,5,6). These calculations have to be repeated using SHADOWV2 and are reported elsewhere (ref. 7). These newer calculations should be used in preference to the earlier calculations. Materials response to exposure correlates very well with atomic oxygen fluence as predicted by the model.

2.0 PROGRAM OPERATION

2.1 DESCRIPTION OF COMPUTER MODEL FOR MICROENVIRONMENT ATOMIC OXYGEN EXPOSURE

The computer model for microenvironment atomic oxygen exposure comprises a suite of programs. The programs that calculate atomic oxygen exposure were all developed at Boeing, and the results are displayed using a commercial software packaged called TECPLOT. (TECPLOT is a product of Amtec Engineering, Inc., P.O. Box 3633, Bellevue, WA 98009-3633.) Elements of the model are shown in the conceptual block diagram of figure 2.1-1; this section gives a brief description of these elements. A more detailed description of the model is given in section 3.0.

After the model description, detailed instructions on how to install and operate the various pieces of the model will be given. They are presented in the order that they will be used: first, how an input file is constructed for SHADOWV2, including the operation of MDDB and AVESHAD; second, how to run SHADOWV2; and last, how to view the results. Appendix A contains sample files generated by all these programs.

2.1.1 Description of Program Modules

Microenvironment Computer Model for Atomic Oxygen Exposure. SHADOWV2 is a FORTRAN program which calculates the atomic oxygen flux on satellite surfaces based on average satellite speed relative to the atmosphere, average atmospheric temperature, and average atomic oxygen density along the satellite's orbit.

The satellite surface is defined by the following geometrical surface elements: trapezoids and sections of cylinders, cones, disks, and spheres. Using combinations of these elements, complex satellite surfaces may be defined. These surfaces may be exposed to atomic oxygen directly or by specular and diffuse reflection from other surfaces. Atomic oxygen arriving at a surface may be destroyed by recombination or surface reaction.

SHADOWV2 calculates the atomic oxygen flux on satellite surfaces as follows: the atomic oxygen flux as a function of direction relative to ram is calculated and stored. Each satellite surface is represented by a grid of points. Direct atomic oxygen may potentially arrive at a point on a surface from any direction in the half sphere above the point; therefore, the half sphere is divided into a grid of zenith and azimuth directions. Each direction is checked to determine if atomic oxygen could arrive from space along that direction. If so, the direct exposure directional flux is tabulated. The fate of a ray of direct flux at the surface is determined by a Monte Carlo technique based on surface properties. The atomic oxygen flux ray may be reflected specularly or diffusely or removed from further consideration by recombination or surface reaction. If a reflection occurs, the ray is propagated either to space or until it strikes another surface (or sometimes the same surface) where the Monte Carlo fate selection is repeated. This propagation process continues until the ray either returns to space or is destroyed by recombination or surface reaction. Similar ray tracing is done for each direction in the half sphere above a point on the surface. When the ray tracing is done for a point, the direct flux at the point from all directions is integrated. Reflected fluxes, recombination, and surface reaction amounts are accumulated.

When the atomic oxygen flux at each surface has been calculated, the fluxes are written to standard output and to a file suitable for plotting by the TECPLOT plotting program.

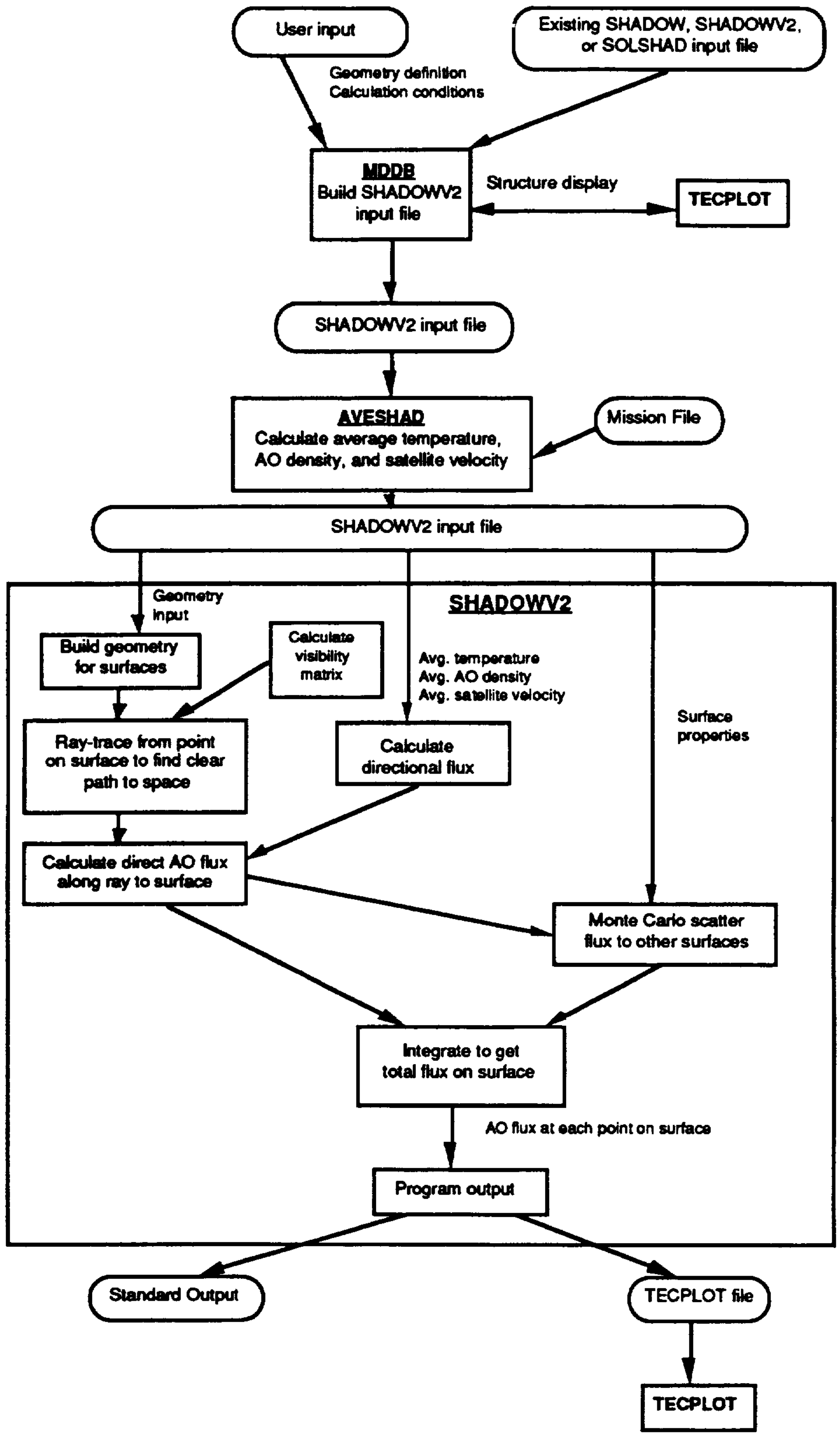

Figure 2.1-1. SHADOWV2 Flow Diagram.

Microenvironment Data Deck Builder Version 2.0. MDDB Version 2.0 is an enhanced and expanded version of the FORTRAN program MDDB Version 1 (ref. 2). While MDDB Version 1 allows users to build or edit input files for the microenvironment atomic oxygen program SHADOW Version 1.X (ref. 1), MDDB Version 2 allows users to build or edit interactively input files for SHADOW Version 1.X, SHADOWV2, and SOLSHAD (ref. 3), as well as to create any of these input files from any of the others. This interconversion is allowed because the three input files have large parts in common. The geometry definition sections of all three are identical except for different surface properties for the atomic oxygen programs and SOLSHAD. Input for SHADOW Version 1.X and SHADOWV2 is identical except that the SHADOWV2 input file does not require a visibility matrix. Calculation control parameters differ between SHADOW, SHADOWV2, and SOLSHAD.

In the remainder of this document, whenever MDDB is mentioned without a version number, the reference is to MDDB Version 2.0.

During the geometry definition phase, MDDB prompts the user for inputs defining surfaces or allows the user to modify or delete existing surfaces, to add new surfaces, or to review or display the surfaces in a structure as far as it has been built. Surface display by the TECPLOT plotting package may be selected throughout the geometry definition phase of input file construction. All surfaces of a structure are displayed with an arrow pointing outward from the active side of each surface. After a surface geometry has been defined, the surface may be translated or rotated to reorient it. This allows the user to define the surface in a convenient set of coordinates and then move it into its true position in a structure.

It should be noted that at all times during display of the structure, the user is out of MDDB (even though MDDB is still opened) and in TECPLOT. Hence, all features of TECPLOT are operative: the plot may be rotated, redisplayed as a wireframe or with shading, probed to determine the coordinates of a surface, printed, etc. When done viewing the TECPLOT display, the user switches back to MDDB while leaving TECPLOT open.

After completion of geometry definition, MDDB prompts the user for parameters controlling SHADOWV2 atomic oxygen calculation and writes the newly created SHADOWV2 input file to a name of the user's choosing.

Calculation of Averaged Values. The output of the computer model for direct atomic oxygen exposure of Earth satellites is a "mission file," which contains data about atomic oxygen as a function of time. This includes (1) average, minimum and maximum of atomic oxygen density, temperature, altitude, absolute speed, and relative speed; and (2) a listing of surfaces making up the exposed geometry of the satellite, their average incidence angles, and calculated atomic oxygen fluxes and fluences for these surfaces as functions of time. A program called AVESHAD has been constructed to take a mission file, a start and end date, and to calculate the average values for atomic oxygen number density for the atmosphere, average temperature of the atmosphere, and average satellite velocity relative to the atmosphere. The program inserts these values into a SHADOWV2 input file.

AVESHAD version 1.0 modified SHADOW version 1.x input files. Because SHADOWV2 input files have a slightly different structure (no visibility matrix), AVESHAD version 2.0 has been created to read SHADOWV2 input files. In all other respects, the programs are identical.

2.1.2 Mainframe and Workstation Platforms

The microenvironments computer model for atomic oxygen exposure SHADOWV2 and its companion programs, MDDB and AVESHAD, generally operate on two platforms: a mainframe and a PC. MDDB is designed to operate in a Microsoft Windows 3.1 environment in conjunction with the commercial software package TECPLOT Version 5.0x. If TECPLOT is available on a more powerful workstation (eg., Sun, Silicon Graphics, Apollo, VAX, etc.), the FORTRAN code for MDDB can be compiled and run on any of those platforms as well, although some modifications may have to be made to the MDDB-generated binary TECPLOT file to be compatible with the installed version of TECPLOT. AVESHAD is also designed to run on a PC or Macintosh; however, if it is more convenient, the C code can be compiled and run on any system that contains a mission file and a SHADOWV2 input file. SHADOWV2 was developed on a CONVEX C2 supercomputer. It generates two files: one that contains all the information from the run, and another that can be imported directly into TECPLOT. The TECPLOT file is transferred to the PC or workstation, where 2D and 3D plots are generated.

2.1.3 Input Files

SHADOWV2 Input File. SHADOWV2 requires a single input file, which it reads from standard input. This file contains a parametric description of the satellite geometry and surface properties and calculation control parameters. A detailed description of the content of this file is given in section 2.2. Most users will find it convenient to use MDDB to construct SHADOWV2 input files.

MDDB Input File. All user input to MDDB is entered interactively from the keyboard in response to prompts displayed on the screen. MDDB prompts the user to supply input for building a new SHADOWV2 input file or for editing an existing SHADOW version 1.X, SHADOWV2 or SOLSHAD input file. Refer to section 2.2 for a detailed description of the SHADOWV2 input file.

AVESHAD Input File. All user input to AVESHAD is entered interactively from the keyboard in response to prompts displayed on the screen. AVESHAD asks for a mission file and a SHADOWV2 input file, and then generates a new SHADOWV2 input file that contains the calculated information.

2.1.4 Output Files

SHADOWV2 Output Files. SHADOWV2 produces two output files. The first is directed to standard output. This file contains an echo of the SHADOWV2 input file, a summary of the object geometry, statistics about the ray tracing calculations, a table of atomic oxygen fluxes at each node, and a listing of the connectivity matrix.

The second file, named TAPE7 as a default, is an ASCII file that contains the coordinates of all the nodes, the atomic oxygen fluence at each node, and a "connectivity matrix" that describes how the nodes are connected to each other. This file is formatted for processing by PREPLOT (a companion program to TECPLOT) to create a binary input file for TECPLOT. TECPLOT displays this file as a plot of the object with the atomic oxygen fluxes color-coded on the surfaces. An exact description of this file is given in Appendix B.

MDDB Output Files. As described in section 2.1.3, MDDB displays prompts on the screen for keyboard input. The output file produced by MDDB is a SHADOW version 1.X, SHADOWV2 or SOLSHAD input file. MDDB also produces a binary TECPLOT and an ASCII TECPLOT file whenever a TECPLOT display of the object is selected. The binary file, MDDB.PLT, may be used directly by the PC version of TECPLOT 5.0x. The ASCII file, MDDB.PRE, must be processed by the TECPLOT companion program PREPLOT before a TECPLOT display can be generated. The ASCII file is provided so that TECPLOT displays can be made using versions of TECPLOT which are incompatible with the binary file. An exact description of these two files are given in Appendix B.

AVESHAD Output File. The file created by AVESHAD is an exact copy of the input file, with new information added in the first four lines, and the new calculated averaged values inserted in their proper locations.

2.2 INPUT FILE CONSTRUCTION

2.2.1 SHADOWV2 Input File

The SHADOWV2 input file divides itself into three natural parts. The first part is a brief event identification section. The second part is a geometry description which defines the surfaces comprising the object or structure whose atomic oxygen exposure is to be modeled. The third part is a set of parameters which controls calculations in SHADOWV2. The three parts are arranged in consecutive order to construct the input file. Figure 2.2.1-1 shows an example of a SHADOWV2 input file, and figure 2.2.1-2 shows a symbolic representation of the format for the five surfaces. (Experienced users who need only look up the formats of the geometry inputs will find this second figure useful.) The SHADOWV2 input file must be directed to standard input when running SHADOWV2.

Event Identification. The atomic oxygen fluxes will be calculated as an average over a period of time, which is referred to as the "event." This is so that various periods within the satellite's mission can be examined. The event must start no earlier than the mission start, and end no later than the mission end.

Record A1 Format (A)

Entry	Type	Variable
One line event description, up to 79 characters.	character	INFO(1)

Record A2 Format (A)

Entry	Type	Variable
Event start date, up to 79 characters.	character	INFO(2)

Record A3 Format (A)

Entry	Type	Variable
Event end date, up to 79 characters.	character	INFO(3)

Record A4 Format (A)

Entry	Type	Variable
Mission file name associated with event, up to 79 characters.	character	INFO(4)

```
Record  12345678901234567890123456789012345678901234567890123456789012345678901234567890

A1      Sample geometry flown for the first month of Space Station Freedom orbit.
A2      EVENT START DATE: 1995   11   30   13   55   21.79
A3      EVENT END DATE:   1995   12   30   13   55   21.79
A4      fluxavg.mission_sample26-Apr-93.1
B1      AN EXAMPLE OF EACH SURFACE TYPE
B2       1    5    5 T T T
B3                -4.0000             -4.0000             15.0000
B4                -4.0000              4.0000             15.0000
B5                 4.0000              4.0000             15.0000
B6                                                         1.0000
B7      PLANE
B8      PLANE MATERIAL
B9          300.00     0.5000     0.5000     0.0000     0.0000     SP,DIF,RE,SR
B2       2    5   24 T T T
B3                 0.0000              0.0000              1.0000
B4                 0.0000              0.0000              0.0000
B5                 1.0000              0.0000              0.0000
B6                 3.0000              1.6667                                  360.0000
B7      CYLINDER
B8      CYLINDER MATERIAL
B9          300.00     0.2500     0.7000     0.0500     0.0000     SP,DIF,RE,SR
B2       3    6   24 T T T
B3                 0.0000              0.0000              1.0000
B4                 0.0000              0.0000              5.0000
B5                 1.0000              0.0000              0.0000
B6                 3.0000              1.6667              0.0000              360.0000
B7      CONE
B8      CONE MATERIAL
B9          300.00     0.3000     0.6000     0.0000     0.1000     SP,DIF,RE,SR
B2       4    4   24 T T T
B3                 0.0000              0.0000              1.0000
B4                 0.0000              0.0000              0.0000
B5                 1.0000              0.0000              0.0000
B6                 6.0000                                  0.5000              360.0000
B7      DISK
B8      DISK MATERIAL
B9          300.00     0.7000     0.2500     0.0500     0.0000     SP,DIF,RE,SR
B2       5    6   24 T T T
B3                 0.0000              0.0000              1.0000
B4                 0.0000              0.0000             12.5000
B5                 1.0000              0.0000              0.0000
B6                 2.5000              0.0000            180.0000              360.0000
B7      SPHERE
B8      SPHERE MATERIAL
B9          300.00     0.0500     0.9000     0.0000     0.0500     SP,DIF,RE,SR
B10      0    0    0 F F F    END OF GEOMETRY
C1      F                    VECTIN
C2       7.276e+05  00.00  000.0  885.25  00.0  1.541e+08       RAM, TATM, ALFREF, AVDEN
C3           20       80       10   T  F  T     NTHETA,NPHI,MAXRAY,SHORTL,CHECK,INACT
C4        997531                  ISEED

Record  12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure 2.2.1-1. Sample SHADOWV2 Input File.

```
Record  1234567890123456789012345678901234567890123456789012345678901234567890123456789
A1      EVENT AND MISSION DESCRIPTION LINE
A2      EVENT START DATE
A3      EVENT END DATE
A4      MISSION FILE NAME
B1      COMMENT ABOUT THE GEOMETRY
B2       1   NC    NN T T T            (T T T = DEBUG FRONT NODESEL)
B3                     P1x                  P1y                 P1z
B4                     P2x                  P2y                 P2z
B5                     P3x                  P3y                 P3z
B6                                                                λ
B7      COMMENT ABOUT THE TRAPEZOID
B8      MATERIAL TYPE
B9          STEMP    SPEC REFL    DIFF REFL    RECOMBINATION   SURFACE REACT
B2       2   NC    NN T T T            (T T T = DEBUG FRONT NODESEL)
B3                      Ex                   Ey                  Ez
B4                      Ax                   Ay                  Az
B5                  Pref x               Pref y              Pref z
B6                       R                  H/R                                     θ
B7      COMMENT ABOUT THE CYLINDER
B8      MATERIAL TYPE
B9          STEMP    SPEC REFL    DIFF REFL    RECOMBINATION   SURFACE REACT
B2       3   NC    NN T T T            (T T T = DEBUG FRONT NODESEL)
B3                      Ex                   Ey                  Ez
B4                      Ax                   Ay                  Az
B5                  Pref x               Pref y              Pref z
B6                    Rmax               H/Rmax           Rmin/Rmax                 θ
B7      COMMENT ABOUT THE CONE
B8      MATERIAL TYPE
B9          STEMP    SPEC REFL    DIFF REFL    RECOMBINATION   SURFACE REACT
B2       4   NC    NN T T T            (T T T = DEBUG FRONT NODESEL)
B3                      Ex                   Ey                  Ez
B4                      Ax                   Ay                  Az
B5                  Pref x               Pref y              Pref z
B6                    Rout                                 Rin/Rout                 θ
B7      COMMENT ABOUT THE DISK
B8      MATERIAL TYPE
B9          STEMP    SPEC REFL    DIFF REFL    RECOMBINATION   SURFACE REACT
B2       5   NC    NN T T T            (T T T = DEBUG FRONT NODESEL)
B3                      Ex                   Ey                  Ez
B4                      Ax                   Ay                  Az
B5                  Pref x               Pref y              Pref z
B6                       R                   φ1                  φ2                 θ
B7      COMMENT ABOUT THE SPHERE
B8      MATERIAL TYPE
B9          STEMP    SPEC REFL    DIFF REFL    RECOMBINATION   SURFACE REACT
10       0    0     0 F F F    END OF GEOMETRY
C1      VECTIN (T = CARTESIAN, F= SPHERICAL)
C2      RAM(1)  RAM(2)  RAM(3)  TATM  ALFREF  AVDEN
C3      NTHETA  NPHI  MAXRAY  SHORTL(T)  CHECK(F)  INACT
C4      ISEED
Record  1234567890123456789012345678901234567890123456789012345678901234567890123456789
```

NOTE: All entries are free format except for record B2 which is format (I2,2I5,3L2) and records B3 through B6 which are format (4F20.10). Some entries in these records are blank.

Figure 2.2.1-2. Symbolic SHADOWV2 Input File.

Geometry Description. A structure is constructed from a series of surfaces. These surfaces may be any combination of up to 100 trapezoids or segments of cylinders, cones, disks, or spheres. It must be emphasized that because they are surfaces and not solids, trapezoids and disks have no depth, cylinders and cones are open on the ends, and spheres are hollow. Each surface has a front or positive side and a back or negative side. Only one side of a surface may be selected for exposure to atomic oxygen. This side is called the active side. Any atomic oxygen striking the unselected side of a surface will be ignored. This may lead to erroneous results. Therefore, the user must be careful when defining which surfaces will be exposed. If the user wants to model atomic oxygen exposure to both sides of a physical surface, he must model the physical surface with two closely spaced surfaces whose active faces point away from each other.

Each surface in a structure is divided into a grid of nodes. Each surface must have at least one node. The total number of nodes for all surfaces may not exceed 5,000. The number of nodes on a surface is the product of the number of nodes NC in the xi (ξ) direction and NN in the eta (η) direction (see record B2 below). Given the choice of constructing a structure having a given total number of nodes with many surfaces and a few nodes on each or a few surfaces with many nodes on each, the latter choice is to be preferred because the time to trace a ray in SHADOWV2 is proportional to the number of surfaces. Therefore, the program will execute more quickly with only a few surfaces.

Atomic oxygen exposure is calculated near each corner of the grid of nodes. The resolution of detail of exposure on a surface thus depends on the number of nodes on a surface. The user should inspect his structure carefully to select noding which gives high resolution in areas where exposure may be expected to vary greatly and lower resolution where the exposure is expected to be more slowly varying.

Because surfaces in SHADOWV2 are not solids, they may overlap or intersect in ways that solids can not. In such cases, a surface may be exposed to atomic oxygen on one side of the intersection or overlap and shielded from it on the other. In some cases the user may wish to take advantage of this; in others, surfaces may inadvertently intersect or overlap, causing unanticipated results. An example of the latter is when two trapezoids are intended to have a common edge; but due to numerical inaccuracy or roundoff, the two trapezoids intersect or overlap near their intended common edge. Whether intended or not, points on the nodes of the intersecting or overlapping surfaces will often show anomalous (and incorrect) atomic oxygen flux. Unintended intersections and overlaps are especially easy to generate when triangles are approximated by trapezoids with a very small (but not zero) ratio of the short to long parallel side to avoid trouble with TECPLOT (see Possible Problems at the end of section 2.2.3) When unintended intersections or overlaps occur, the user should adjust the geometry of surfaces in the structure to remove the problem. It should be noted that small gaps between the edges of surfaces seldom have a great effect on modeled atomic oxygen fluxes. When the intersections or overlaps are intended, the region of incorrect atomic oxygen flux may be minimized by using a fine grid.

Refer to figures 2.2.1-1 and 2.2.1-2 for samples of SHADOWV2 input files. The geometry description takes place in records labeled B1 through B10 for this example with five surfaces. Before giving complete definitions for these records, a few words about the structure of the surface definition records is in order. Record B1 is a text description of the structure and is entered only once. Records B2 through B9 are repeated once for each surface in the structure. Records B2 through B6 define the surface type and geometry. Record B7 contains a text description of the surface. Records B8 and B9 describe and define surface properties. Record B10 terminates the geometry input.

Record B1 Format (A)

Entry	Columns	Type	Variable
Description of geometry.	1-60	character	HEADER

This record is entered once only.

Records B2 through B9 are repeated in sequence for each surface.

Record B2 Format (I2,2I5,3L2)

Entry	Columns	Type	Variable
Surface type 1 = trapezoid 2 = cylinder 3 = cone 4 = disk 5 = sphere.	1-2	integer	IP(IPS,1)
Number of nodes in xi direction. Refer to figures 2.2.1-3 through 2.2.1-7 for orientation of nodes.	3-7	integer	IP(IPS,2) or NC
Number of nodes in eta direction. Refer to figures 2.2.1-3 through 2.2.1-7 for orientation of nodes.	8-12	integer	IP(IPS,3) or NN
Debug flag. If T (true), select normal output[1]. If F (false), select full debug output for geometry. F (false) is rarely used because it generates an excessively large output.	13-14	logical	F(13) or LASTF
Flag to designate active side of surface. If T (true), select front (positive) side of surface. If F (false), select back (negative) side of surface	15-16	logical	F(15) or FRONT
Flag to select whether flux on this surface is to be calculated. If T (true), calculate flux on surface[2]. If F (false), do not calculate flux on surface. F (false) is rarely used because careless use may cause erroneous results.	17-18	logical	F(16) or NODESEL

The contents of records B3 through B6 depend on which surface has been selected in record B2.

Surface Type 1: TRAPEZOID (figure 2.2.1-3). The trapezoid is defined by three points and the ratio of the length of the parallel sides. This ratio, λ, must be $0 \leq \lambda \leq 1$. Let P1 and P2 be the points located at the ends of the longer of the two parallel sides. P3 is an end point on the shorter parallel side such that P2 is connected to P1 and P3. A triangle can be made by setting $\lambda = 0$. The positive side of the surface is defined such that the corner points are ordered in counterclockwise manner when the positive side is visible. This is the conventional right-hand rule.

[1]MDDB automatically selects this entry. Users wishing to enter F (false) must edit their input files outside MDDB.
[2]MDDB automatically selects this entry. Users wishing to enter F (false) must edit their input files outside MDDB.

Record B3 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of P1.	1-20	real	P(IPS,1)
Y coordinate of P1.	21-40	real	P(IPS,2)
Z coordinate of P1.	41-60	real	P(IPS,3)

Record B4 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of P2.	1-20	real	P(IPS,4)
Y coordinate of P2.	21-40	real	P(IPS,5)
Z coordinate of P2.	41-60	real	P(IPS,6)

Record B5 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of P3.	1-20	real	P(IPS,7)
Y coordinate of P3.	21-40	real	P(IPS,8)
Z coordinate of P3.	41-60	real	P(IPS,9)

Record B6 Format (20X,F20.10)

Entry	Columns	Type	Variable
Ratio of short to long parallel sides of trapezoid, λ.	21-40	real	C(4)

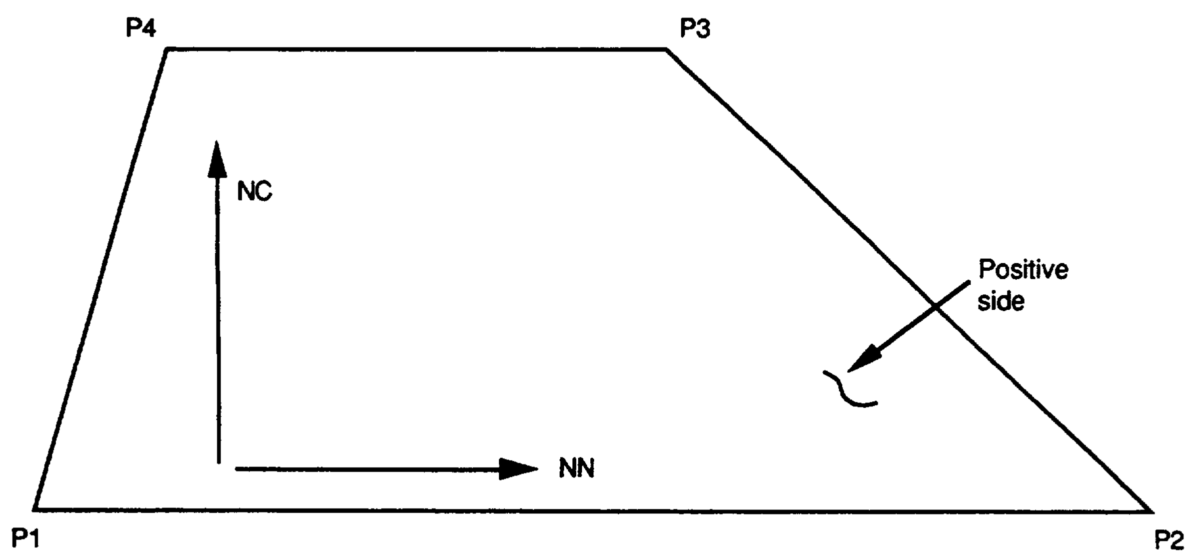

Figure 2.2.1-3. Trapezoid.

Surface Type 2: CYLINDER (figure 2.2.1-4). The cylinder is defined by an axial vector E, a center point A, a reference point P_{ref}, the radius R, the ratio of height to the radius H/R, and the angular extent θ. The axial vector **E** points from the center point A through the cylinder. The reference point P_{ref} and the axial vector **E** specify a half plane from which the angular extent of the cylinder θ is measured. θ is measured in the right hand rule sense with respect to the direction of E. The positive side of the cylinder is the outside.

Record B3 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of axial vector E.	1-20	real	P(IPS,1)
Y coordinate of axial vector E.	21-40	real	P(IPS,2)
Z coordinate of axial vector E.	41-60	real	P(IPS,3)

Record B4 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of center A.	1-20	real	P(IPS,4)
Y coordinate of center A.	21-40	real	P(IPS,5)
Z coordinate of center A.	41-60	real	P(IPS,6)

Record B5 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of reference point P_{ref}.	1-20	real	P(IPS,7)
Y coordinate of reference point P_{ref}.	21-40	real	P(IPS,8)
Z coordinate of reference point P_{ref}.	41-60	real	P(IPS,9)

Record B6 Format (2F20.10,20X,F20.10)

Entry	Columns	Type	Variable
Radius of cylinder R.	1-20	real	C(2)
Ratio of cylinder height to radius H/R.	21-40	real	C(3)
Angular extent of cylinder θ. $0 < \theta \leq 360$ degrees.	61-80	real	C(5)

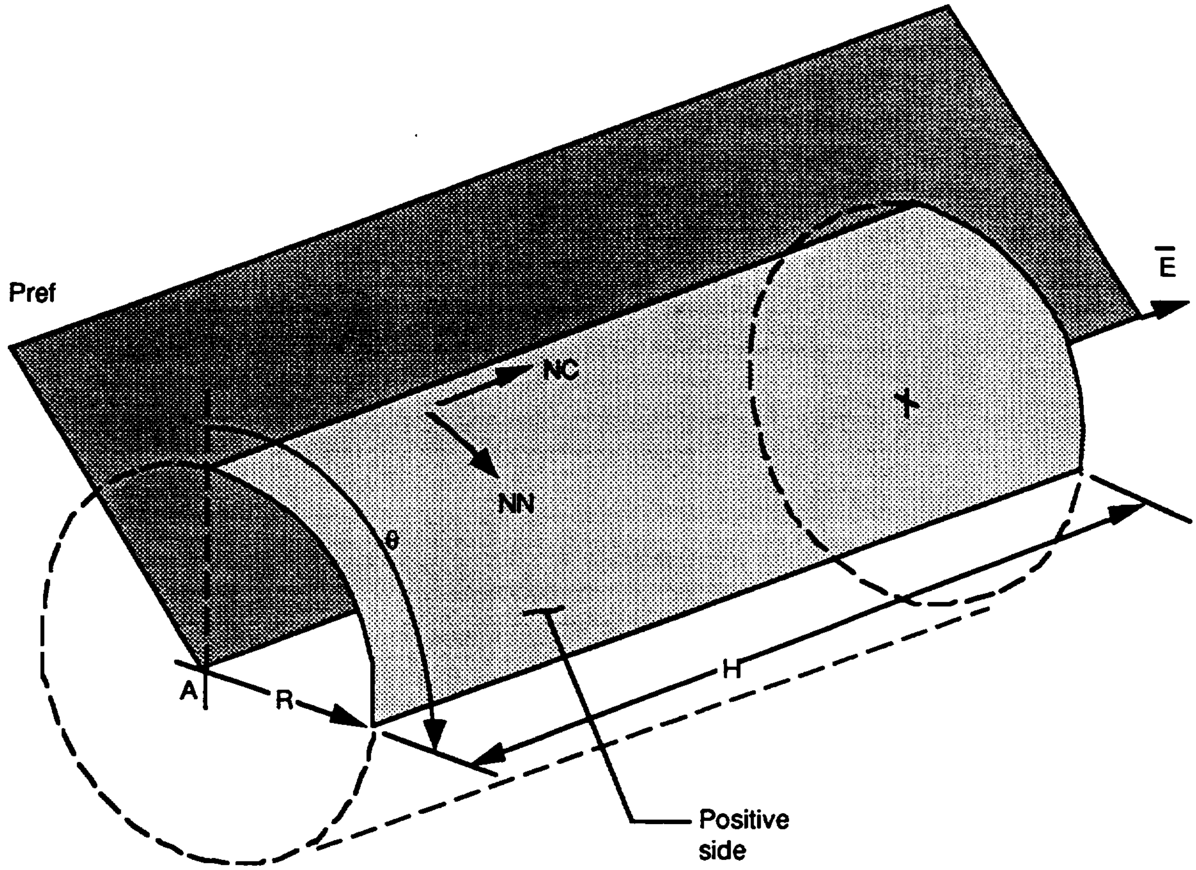

Figure 2.2.1-4. Cylinder.

Surface Type 3: CONE (figure 2.2.1-5). The cone is defined similarly to the cylinder. The cone is defined by an axial vector **E**, a center point A, a reference point P_{ref}, a maximum radius R_{max}, the ratio of height to the maximum radius H/R_{max}, the ratio of the minimum to maximum radius R_{min}/R_{max}, and the angular extent θ. The axial vector **E** points from the center point A through the cone. The reference point P_{ref} and the axial vector **E** specify a half plane from which the angular extent of the cone θ is measured. θ is measured in the right hand rule sense with respect to the direction of E. The positive side of the cone is the outside.

Record B3 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of axial vector **E**.	1-20	real	P(IPS,1)
Y coordinate of axial vector **E**.	21-40	real	P(IPS,2)
Z coordinate of axial vector **E**.	41-60	real	P(IPS,3)

Record B4 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of center A.	1-20	real	P(IPS,4)
Y coordinate of center A.	21-40	real	P(IPS,5)
Z coordinate of center A.	41-60	real	P(IPS,6)

Record B5 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of reference point P_{ref}.	1-20	real	P(IPS,7)
Y coordinate of reference point P_{ref}.	21-40	real	P(IPS,8)
Z coordinate of reference point P_{ref}.	41-60	real	P(IPS,9)

Record B6 Format (4F20.10)

Entry	Columns	Type	Variable
Maximum radius of cone R_{max}.	1-20	real	C(2)
Ratio of cone height to radius H/R_{max}.	21-40	real	C(3)
Ratio of cone minimum to maximum to radius R_{min}/R_{max}.	41-60	real	C(4)
Angular extent of cone θ. $0 < \theta \leq 360$ degrees.	61-80	real	C(5)

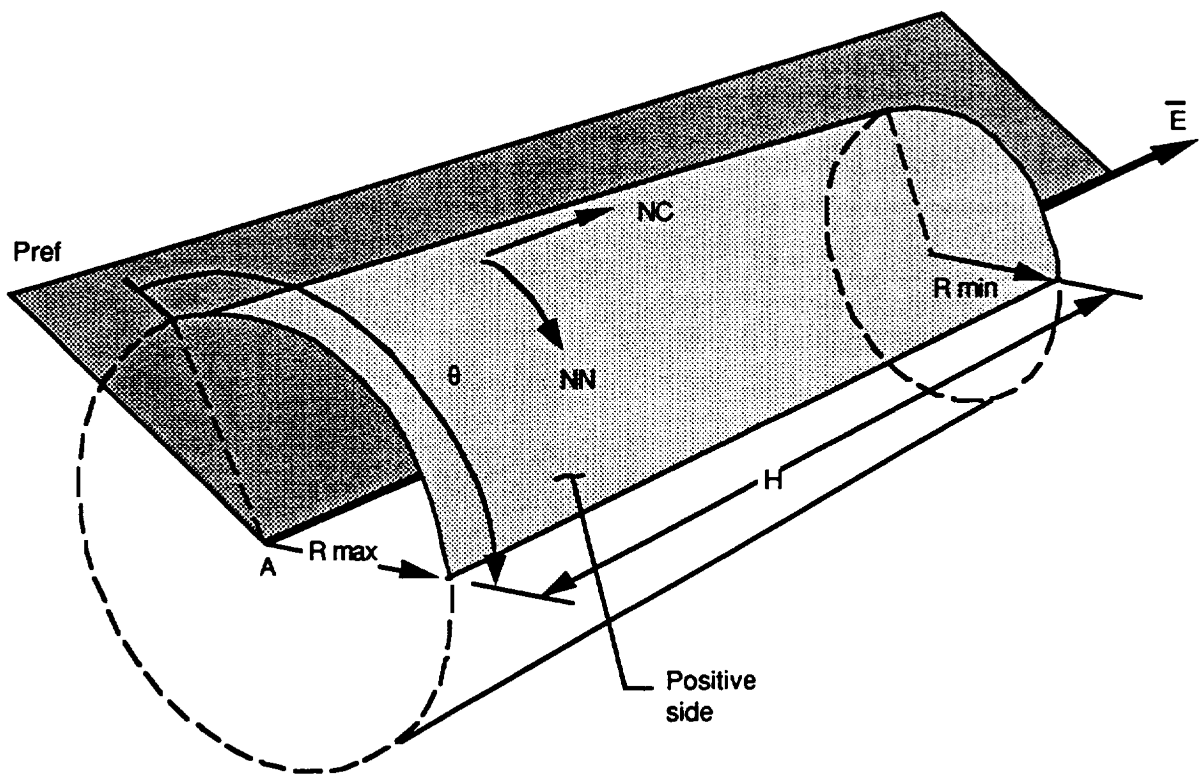

Figure 2.2.1-5. Cone.

Surface Type 4: DISK (figure 2.2.1-6). The disk is defined by an axial vector **E**, a center point A, a reference point P_{ref}, an outer radius R_{out}, an inner radius R_{in}, the ratio of the inner to outer radius R_{in}/R_{out}, and the angular extent θ. The reference point P_{ref} and the axial vector **E** specify a half plane from which the angular extent of the disk θ is measured. Note that θ is measured in the **left** hand rule sense with respect to the direction of **E**. The positive side of the disk is the side whose outward surface normal is parallel to E.

Record B3 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of axial vector **E**.	1-20	real	P(IPS,1)
Y coordinate of axial vector **E**.	21-40	real	P(IPS,2)
Z coordinate of axial vector **E**.	41-60	real	P(IPS,3)

Record B4 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of center A.	1-20	real	P(IPS,4)
Y coordinate of center A.	21-40	real	P(IPS,5)
Z coordinate of center A.	41-60	real	P(IPS,6)

Record B5 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of reference point P_{ref}.	1-20	real	P(IPS,7)
Y coordinate of reference point P_{ref}.	21-40	real	P(IPS,8)
Z coordinate of reference point P_{ref}.	41-60	real	P(IPS,9)

Record B6 Format (F20.10,20X,2F20.10)

Entry	Columns	Type	Variable
Outside radius of disk R_{out}.	1-20	real	C(2)
Ratio of inside to outside radius of disk R_{in}/R_{out}.	41-60	real	C(4)
Angular extent of cone θ. $0 < \theta \leq 360$ degrees. Note that this is measured in the left hand rule sense.	61-80	real	C(5)

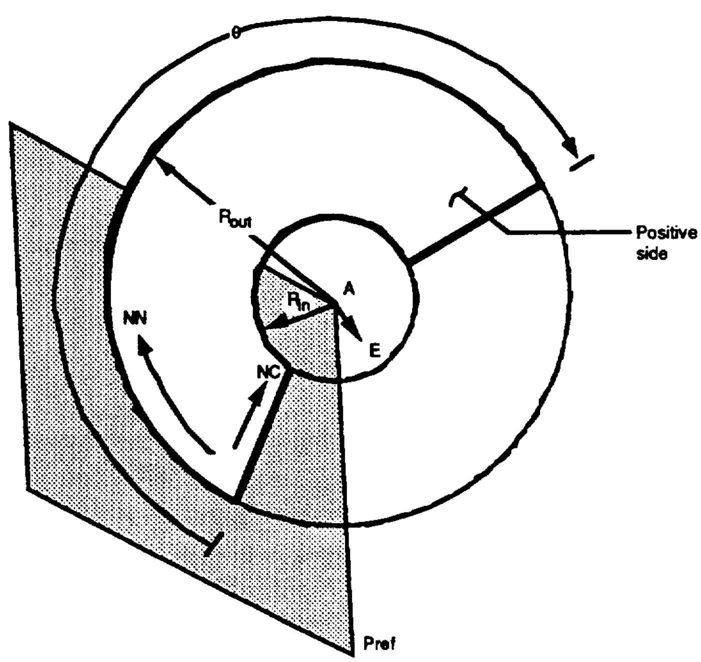

Figure 2.2.1-6. Disk.

Surface Type 5: SPHERE (fig. 2.2.1-7). The sphere is defined by an axial vector **E** along the polar axis, a center point A, a reference point P_{ref}, the radius R, the azimuthal angular extent θ, and two angles defining the polar (zenith) angular extent ϕ_1 and ϕ_2, with ϕ_1 being the smaller angle. The axial vector **E** points from the center point A through the north pole of the sphere. The reference point P_{ref} and the axial vector **E** specify a half plane from which the azimuthal angular extent of the sphere θ is measured. θ is measured in the right hand rule sense with respect to the direction of **E**. The positive side of the sphere is the outside.

Record B3 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of axial vector **E**.	1-20	real	C(1)
Y coordinate of axial vector **E**.	21-40	real	C(2)
Z coordinate of axial vector **E**.	41-60	real	C(3)

Record B4 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of center A.	1-20	real	C(5)
Y coordinate of center A.	21-40	real	C(6)
Z coordinate of center A.	41-60	real	C(7)

Record B5 Format (3F20.10)

Entry	Columns	Type	Variable
X coordinate of reference point P_{ref}.	1-20	real	C(9)
Y coordinate of reference point P_{ref}.	21-40	real	C(10)
Z coordinate of reference point P_{ref}.	41-60	real	C(11)

Record B6 Format (4F20.10)

Entry	Columns	Type	Variable
Radius of sphere R.	1-20	real	C(13)
Smaller polar angle limit ϕ_1. $0 < \phi_1 < \phi_2$ degrees.	21-40	real	C(14)
Larger polar angle limit ϕ_2. $\phi_1 < \phi_2 \leq 180$ degrees.	41-60	real	C(15)
Azimuthal extent of cone θ. $0 < \theta \leq 360$ degrees.	61-80	real	C(16)

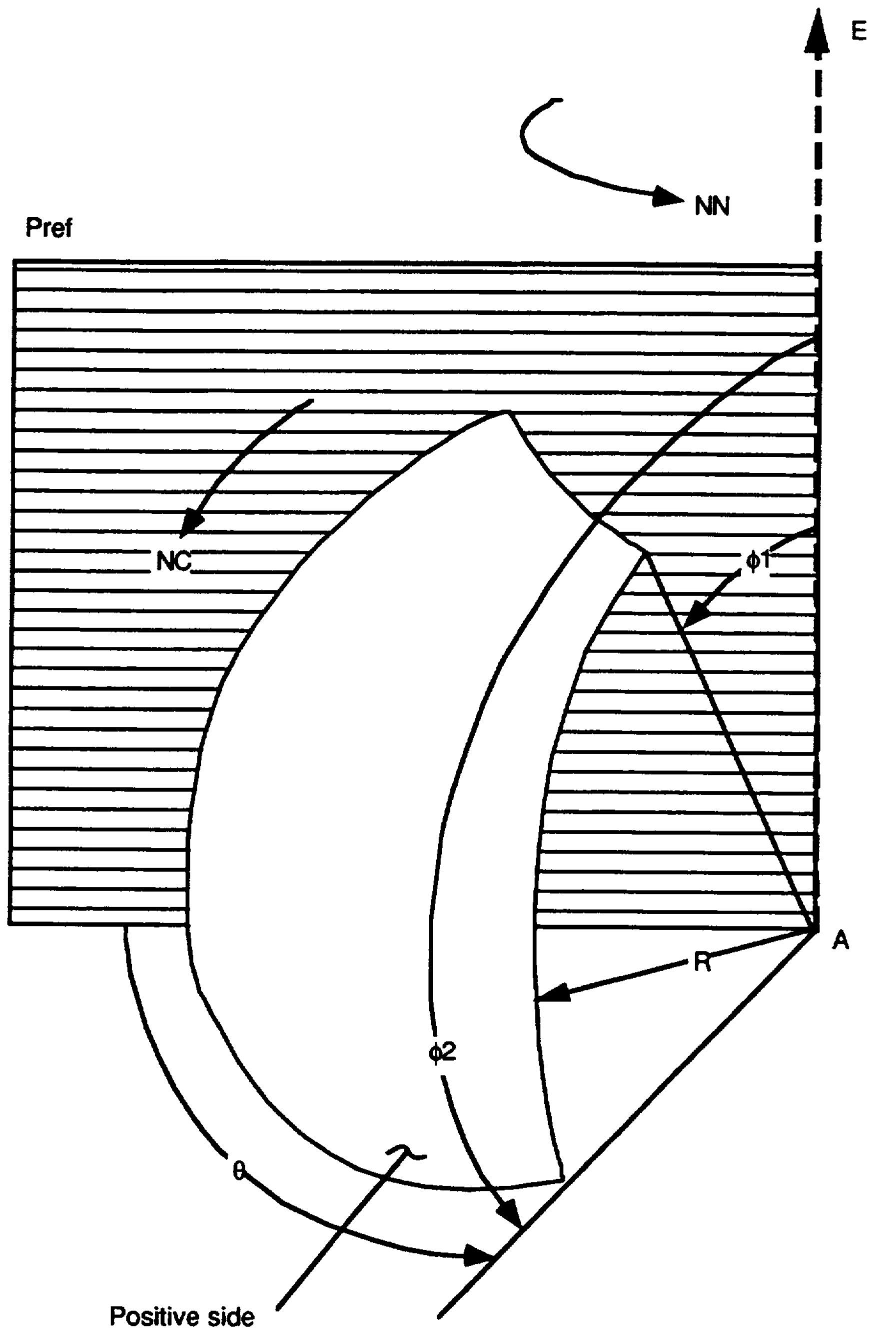

Figure 2.2.1-7. Sphere.

Record B7 Format (A)

Entry	Columns	Type	Variable
A comment about the surface.	1-40	character	C(31)-C(40) or P(IPS,17)-P(IPS,26)

Record B8 Format (A)

Entry	Columns	Type	Variable
The name of the surface material.	1-80	character	SNAME

Record B9 Free Format

Entry	Type	Variable
Temperature of surface.	real	STEMP
Specular reflectivity of surface for atomic oxygen.	real	SPROP(1,IPS)
Diffuse reflectivity of surface for atomic oxygen.	real	SPROP(2,IPS)
Atomic oxygen recombination efficiency at surface.	real	SPROP(3,IPS)
Surface reactivity of atomic oxygen for surface.	real	SPROP(4,IPS)

The surface properties specify what fraction of incident atomic oxygen flux on the surface is specularly reflected, diffusely reflected, recombined to form O_2, and reacted on the surface. These four fractions must sum to one.

Data on material surface properties for atomic oxygen exposure are not well established. Further research needs to be done to determine these parameters. Table 2.2.1-1 is the authors' best estimates of surface properties of some materials. Simulations that used this data are also mentioned.

Table 2.2.1-1
Atomic Oxygen Surface Properties of Some Materials

Material	Specular Reflection	Diffuse Reflection	Recombination Efficiency	Surface Reactivity	Used to Model
Aluminum	0.50	0.46	0.04	0.00	1, 3, 4, 5, 6, 7, 8, 9
Kapton	0.40	0.45	0.15	0.00	1
FEP (Aluminized Teflon)	0.98	0.00	0.00	0.02	2, 3, 4, 5, 8
Copper	0.50	0.40	0.08	0.02	5, 9
Polyethylene	0.40	0.40	0.00	0.20	7
Gold	0.65	0.20	0.00	0.15	7
Silica Glass	0.67	0.33	0.00	0.0002	8
Silver Oxide	0.25	0.25	0.50	0.00	9

Simulations:

1. EOIM3 experiment
2. Trap clamp row 9 FEP surface (LDEF)
3. Trap B-7 FEP blanket fold at longeron (LDEF)
4. Tray D-11 FEP blanket fold at tray edge (LDEF)
5. Tray D-11 copper ground strap (LDEF)
6. Inside of box exposed to ram
7. Indirect scattering test
8. Space Station Freedom cupola side window cross section
9. Part of AO171 samples on row 8 (LDEF)

Record B10 Format (I2,2I5,3L2)

Entry	Columns	Type	Variable
0	1-2	integer	IP(IPS,1)
0	3-7	integer	IP(IPS,2) or NC
0	8-12	integer	IP(IPS,3) or NN
F (false).	13-14	logical	F(13) or LASTF
F (false).	15-16	logical	F(15) or FRONT
F (false).	17-18	logical	F(16) or NODESEL

This card signals the end of geometry input. It is input only once. The entries are required for proper geometry termination and for compatibility with MDDB.

Calculation Control Parameters. The calculation control parameters on the following four records determine the conditions under which atomic oxygen flux calculations take place. Also, one can obtain the unshielded direct flux on a hypothetical reference surface whose orientation is defined in this section. This flux can be compared to the flux on real surfaces of the object.

The number of rays used in the calculation are determined by the values NTHETA, NPHI and MAXRAY in record C3. No hard and fast rules for the selection of these variables can be given; users must depend on their knowledge of the geometry being modeled and their experience. However, the authors have found that values of MAXRAY = 10, NTHETA = 40, and NPHI = 160 are good starting values and suggest the following guidelines for further refinement.

The flux on each node on a surface is determined by calculating the flux from each direction along an angular grid on the half sphere centered on the active side surface normal at the point and integrating over the half sphere. NTHETA and NPHI define the elevation and azimuth increments on the grid. Selection of NTHETA and NPHI depends on several factors. The grid should be fine enough to image accurately the horizon of shadowing surfaces seen by the point. Also, SHADOWV2 is currently set to accept a maximum of MAXBIN = 10000 grid elements = NTHETA times NPHI (see section 2.3.1 and table 2.3.1-3 if this maximum is to be changed). The authors have found that setting NTHETA to 40 and NPHI to 160 (that is, angular grid elements of 2.25 by 2.25 degrees) is adequate for most occasions. Because the execution speed of SHADOWV2 is approximately proportional to the number of grid elements, users may want to try coarser grid elements to speed up SHADOWV2. However, they should be careful that the coarser grid does not reduce the accuracy of their results. If the horizon seen by a point on a surface has significant variations on an angular scale finer than 2.25 by 2.25 degrees, the user should adjust NTHETA and NPHI to resolve the horizon, especially if he expects a high directional flux to come from the direction of the horizon.

Each ray striking a node on a surface from one of the directions in the NTHETA-NPHI grid is divided into rays of equal intensity. Each of these rays is Monte Carlo scattered as described in sections 3.1.1 and 3.2.1. MAXRAY governs how many rays are scattered. MAXRAY is an areal density and specifies the number of rays scattered from a node whose area is the average of the areas of all of the nodes on all of the surfaces in the object. The number of rays scattered from a node is proportional to MAXRAY times the area of the node divided by the average node area. Thus, large nodes will have many rays scattered from them and small nodes may have few or no rays scattered from them. The user should adjust MAXRAY so that at least all important nodes (in this case, those which are expected to scatter significant amounts of AO flux) scatter at least a few rays. A useful way to estimate if enough rays are being scattered is to submit SHADOWV2 interactively with standard output sent to the terminal. After the information about how many rays are scattered from the smallest node is displayed, terminate the program. (This occurs after the visibility matrix is generated, but just before the main ray-tracing calculations take place. You should see the information about the smallest node just before the program stops at its longest pause.) Examine this number and adjust MAXRAY to an appropriate value. If MAXRAY is set to 0, only direct exposure to surfaces is calculated; no reflections are considered.

Record C1 Free Format

Entry	Type	Variable
T (true) if satellite heading vector is to be entered in Cartesian coordinates. F (false) if in spherical coordinates.	logical	VECTIN

Record C2 Free Format

If VECTIN = T

Entry	Type	Variable
x component of the average satellite heading vector relative to the atmosphere (cm/s).	real	RAM(1)
y component of the average satellite heading vector relative to the atmosphere (cm/s).	real	RAM(2)
z component of the average satellite heading vector relative to the atmosphere (cm/s).	real	RAM(3)
Average atmospheric temperature (K).	real	TATM
Angle between satellite heading vector and a hypothetical reference surface (degrees).	real	ALFREF
Average atomic oxygen density (atoms/cm^3)[3].	real	AVDEN

If VECTIN = F

Entry	Type	Variable
Magnitude of the average satellite heading velocity relative to the atmosphere (cm/s).	real	RAM(1)
Zenith angle (degrees) of the average satellite heading velocity relative to the atmosphere measured from coordinate z axis.	real	RAM(2)
Azimuth angle(degrees) of the average satellite heading velocity relative to the atmosphere measured from the coordinate x axis toward the y axis.	real	RAM(3)
Average atmospheric temperature (K).	real	TATM
Angle between satellite heading vector and a hypothetical reference surface (degrees).	real	ALFREF
Average atomic oxygen density (atoms/cm^3).	real	AVDEN

---

[3] When entered as indicated, AVDEN results in calculation of atomic oxygen fluxes on surfaces. Users will note that because fluence is flux times mission time, entering AVDEN times mission time here will result in atomic oxygen fluences on surfaces.

Record C3 Free Format

Entry	Type	Variable
Number of elevation increments for ray aiming.	integer	NTHETA
Number of azimuth increments for ray aiming.	integer	NPHI
Number of rays per average node area to scatter from each angular direction during Monte Carlo scattering. The areal density of rays specified by MAXRAY is scattered from each node on the structure. If MAXRAY = 0, only direct AO fluxes are calculated.	integer	MAXRAY
If T (true), do not list the coordinates of each node on the surface of the object at each step of the ray tracing[4]. If F (false), list the coordinates of each point on the surface of the object at each step of the ray tracing. This option should be used only for debugging; it produces a very lengthy output.	logical	SHORTL
If T (true), calculate coordinates of points on surfaces of object, but do not calculate fluxes. If F (false), calculate fluxes on surfaces of object[5].	logical	CHECK
If T (true), do not print out rays which intersect the inactive side of surfaces during automatic generation of the visibility matrix. If F (false), print out these rays.	logical	INACT

See the explanation above for the determination of NTHETA, NPHI, and MAXRAY values.

Record C4 Free Format

Entry	Type	Variable
Random number generator seed (an integer between 1 and 7 digits).	integer	ISEED

2.2.2 Installation of the Geometry Builder

The Geometry Builder consists of two separate programs: MDDB (for Microenvironment Data Deck Builder) and TECPLOT (a commercial 3D plotting application). These two programs are run simultaneously, using a windowing system that allows switching between them. MDDB asks for geometries, and collects information to build a SHADOW (ref. 2), SHADOWV2, or SOLSHAD (ref. 3) input file. At various times it is possible to pause in the middle of MDDB, have it write a file for TECPLOT, and then switch to TECPLOT in order to view the progress.

This section describes how to install and run these two programs on a PC in the Microsoft Windows environment (version 3.0 or higher). TECPLOT is also available for other types of workstations, and MDDB and TECPLOT can be run in a similar manner on these workstations.

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[4]MDDB automatically selects this entry. Users wishing to enter F (false) must edit their input files outside MDDB.
[5]MDDB automatically selects this entry. Users wishing to enter T (true) must edit their input files outside MDDB. The true entry has been rendered obsolete by the development of MDDB.

FORTRAN code for MDDB is included; compile it on the workstation and run the two programs in separate windows. To recompile the code for Microsoft Windows on a PC, use the Microsoft FORTRAN compiler (version 5.0 or higher) with the Microsoft Windows compiler option (**fl /FeMDDB /MW *.for**).

Note: Users of SHADOW (ref. 2) will note that MDDB version 1 and MDDB version 2 share a number of subroutine names in common. Although their names are the same, these subroutines are different and cannot be interchanged between the two codes.

In this section, commands that the user types are written in **bold**, computer displays are written in **helvetica**, and file names are written in `courier`.

Installation for Microsoft Windows

1. Copy the following files from disk into the same directory that contains TECPLOT:
   `mddb2.exe`
   `p.mcr`
   `table.mcr`
   `shadow.mcr`

   Note: The TECPLOT macro files (those ending in `.mcr`) that you should copy will depend on the version of TECPLOT that you are using. For version 5 on a PC, copy the files from the directory `tec5pc`. For version 5 on a workstation, copy the files from the directory `tec5ws`. For version 6 on a PC, copy the files from the directory `tec6pc`. For version 6 on a workstation, copy the files from the directory `tec6ws`.

2. Copy the following file from disk into the same directory that contains Windows:
   `tecplot.pif`

3. Edit the TECPLOT configuration file (`tecplot.cfg` in the directory that contains TECPLOT), and make sure that the 3D aspect ratio limit is 100,000 or higher. This will prevent flat figures from becoming distorted.

4. Start up Microsoft Windows by typing `win`.

5. Create a Microenvironments Group.
   a. Open up the Program Manager Window.
   b. Choose **New** from the **File** Menu.
   c. Choose **Program Group** and **OK**.
   d. In the **Description** box, type **Microenvironments**.
   e. In the **Group File** box, type **mddb.grp**. Hit **OK**.

6. Add an icon for MDDB. (Except for the Description box, the values typed in are not case sensitive.)
   a. Choose **New** from the **File** Menu.
   b. Choose **Program Item** and **OK**.
   c. In the **Description** box, type **MDDB**.
   d. In the **Command Line** box, type **mddb2.exe**.
   e. In the **Working Directory** box, type **C:\tecplot** (or whatever the directory is that contains TECPLOT and `mddb.exe`).
   f. Leave "None" in the **Shortcut Key** box type.

g. Choose an icon by clicking on the **Change Icon** button. We suggest a simple window icon.

h. Click on **OK**. The new icon labeled MDDB should appear in the new window.

7. Add an icon for TECPLOT. (Except for the Description box, the values typed in are not case sensitive.)

a. Choose **New** from the **File** Menu.

b. Choose **Program Item** and **OK**.

c. In the **Description** box, type **Tecplot**.

d. In the **Command** box, type **c:\windows\tecplot.pif** (or whatever path gets into the windows directory).

e. In the **Working Directory** box, type, **C:\tecplot** (or whatever the directory is that contains TECPLOT and `mddb.exe`).

f. Leave "None" in the **Shortcut Key** box.

g. Choose an icon by pressing the **Change Icon** button. We suggest a 3D graph icon if available.

h. Click on **OK**. The new icon labeled Tecplot should appear in the window. Size and move the window by clicking and dragging on the bottom corner and top bar, respectively.

2.2.3 Constructing Input Geometries Using MDDB and TECPLOT

This section describes how to operate MDDB and TECPLOT simultaneously on Microsoft Windows so that an input file can be viewed as it is being constructed. First, it is necessary to open two windows: one that contains MDDB, and the other containing TECPLOT. At various times during MDDB operation, you will be asked if you want a TECPLOT display. If you respond "yes," MDDB will generate a file for TECPLOT, and then pause. You will then switch to the TECPLOT window, run a macro to call up the file that was generated and display it. You may then rotate and view the object using standard TECPLOT commands. Once you are finished, you will return to the MDDB window.

MDDB will ask for data with which to build the input file. MDDB version 2 has an improvement over version 1 in that it will display default data or data from a file being edited and ask if you want to keep these data or enter new data. By entering an equal sign (=), the old data will be used; any other input will be taken as new data.

Setting up Windows for TECPLOT and MDDB

1. Start up Microsoft Windows.

2. Double-click on Tecplot. After about 10 seconds, the TECPLOT screen will appear. Hit the space bar.

3. Type <Cntl><Escape>. Windows will return, and a box will appear. Double-click on **Program Manager**.

4. Double-click on MDDB icon. A window will appear labeled **MDDB - [Unit *]**.

Constructing Geometries Using MDDB

1. You are asked for the file format of the file you will be creating. Choose 2 for SHADOWV2. (You also have the option of choosing 1 for SHADOW version 1.x input files or 3 for SOLSHAD input files.)

2. You are asked whether to create a new file or edit an existing one. Enter 1 for a new file, or 2 for the existing file. If you have modeled a geometry using SHADOW version 1.x or SOLSHAD, you can edit the previous geometry and create a SHADOWV2 input file.

3. If a new file is chosen, you are asked for an event description, start and end dates, a mission file name, and a descriptive header for the data file. If you plan to use the program AVESHAD to automatically calculate the averaged values for a given event, then the first four lines will be automatically replaced. During MDDB, you may simply type "unknown."

4. If an existing file is chosen, enter the file name at the next prompt. Then enter the file type: 1 for SHADOW version 1.x, 2 for SHADOWV2, or 3 for SOLSHAD (if you give the wrong file type, a program error will occur which will halt MDDB). You are then shown the first four lines if a SHADOWV2 file has been selected (event description, start and end dates, and mission file name), and asked if you want to modify them. If yes, then you are prompted for each of the lines. If no, enter = to accept them. Again, if you plan to use the program AVESHAD, then these first four lines will be automatically replaced.

5. You are then presented with the main menu. (If creating a new file, you are automatically sent into option 1.)

```
SELECT AN ACTION BY NUMBER FROM THE LIST
1  ADD ANOTHER SURFACE AT END OF SURFACES
2  MODIFY AN EXISTING SURFACE
3  DELETE A SURFACE
4  INSERT A NEW SURFACE
5  REVIEW SURFACES
6  COPY SURFACE AND INSERT IT AT A NEW POSITION
7  EXIT SURFACE OPERATIONS (DONE)
```

6. To add another surface at the end of the existing surfaces:
   a. Select 1.
   b. MDDB gives you the "current definition" of the new surface, which is meaningless. Press return to enter the new data.
   c. Choose a surface type (1 = trapezoid, 2 = cylinder, 3 = cone, 4=disk, and 5 = sphere.)
   d. You will be prompted for all the information that describes the geometry. (These values are described in detail in section 2.2.1.) If you are prompted for several values on one line, separate them by space or commas. For example, to enter the coordinates (4.0, -2, 1.3), type **4.0 -2 1.3** or **4.0,-2,1.3.**)
   e. You are then asked if you want to see a TECPLOT display. If you answer yes, follow the instructions in the next section.
   f. You are to verify if the surface is correct. If not, you are prompted to enter data for the surface again.
   g. You are asked if you want to rotate or translate the surface. If yes, you are given the following menu:

```
SELECT ACTION
 T  TRANSLATE SURFACE
 X  ROTATE ABOUT X AXIS
 Y  ROTATE ABOUT Y AXIS
 Z  ROTATE ABOUT Z AXIS
```

h. Enter the menu choice, and then how you much you want the surface rotated or translated[6].
i. Again, you are asked if you want to see a TECPLOT display. If yes, follow the instructions in the next section.
j. At this point, you have the chance to undo the operation if it doesn't look right.
j. Further translation and rotation is available at this point.
k. Finally, the main menu is displayed again.

7. To modify an existing surface:
   a. Select 2.
   b. A list of surfaces is displayed. Choose the number of the surface you want to modify.
   c. The following menu is shown:

```
SELECT AN ACTION BY NUMBER
  1  MODIFY DATA FOR THE SURFACE
  2  ROTATE OR TRANSLATE THE SURFACE
  3  DISPLAY GEOMETRY AND SURFACE DATA FOR THE SURFACE
  4  FINISHED MODIFICATION OF THIS SURFACE
```

   d. Choose the appropriate actions, until the surface is to your satisfaction. At various times, you will be given the option to view the surface in TECPLOT. When finished with the surface, choose number 4. The main menu will be displayed.

8. To delete a surface:
   Note: Be careful -- this operation cannot be undone.
   a. Select 3.
   b. A list of surfaces is displayed. Choose the number of the surface you want to delete.
   c. The surface is deleted. The main menu will then be displayed.

9. To insert a new surface:
   a. Select 4.
   b. A list of surfaces is displayed. Choose the number of the surface in front of which you would like the new surface to be inserted.
   c. Enter information just as in step 6.

10. To review surfaces:
   a. Select 5.
   b. A list of surfaces is displayed. Choose the number of the surface you want to review. Zero reviews all surfaces.
   c. You are shown the properties of that surface, and then given the option to get a TECPLOT display of the structure.
   d. If you chose to review all surfaces, the program steps you through each surface, asking if you want to see a TECPLOT display at any point.

11. To copy a surface:
   Note: This menu option is very useful for building structures which contain surfaces which are identical except for positions.
   a. Select 6.
   b. A list of surfaces is displayed. Choose the number of the surface you want to copy.

---

[6]Note that rotations actually take place about an axis through a user-selected point parallel to the selected coordinate axis of rotation rather than the coordinate axis itself. This allows the user great flexibility when rotating surfaces. For example, consider a rectangle initially in the Y-Z plane and intersecting the X axis at x_o as shown in figure 2.2.3-1(a). If this rectangle is rotated by 90 degrees about the Z axis, with (0,0,0) as the rotation point, it is transformed to the position shown in figure 2.2.3-1(b). However, if the rotation point is taken to be $(x_o,0,0)$, the rectangle is transformed to the position shown in figure 2.2.3-1(c).

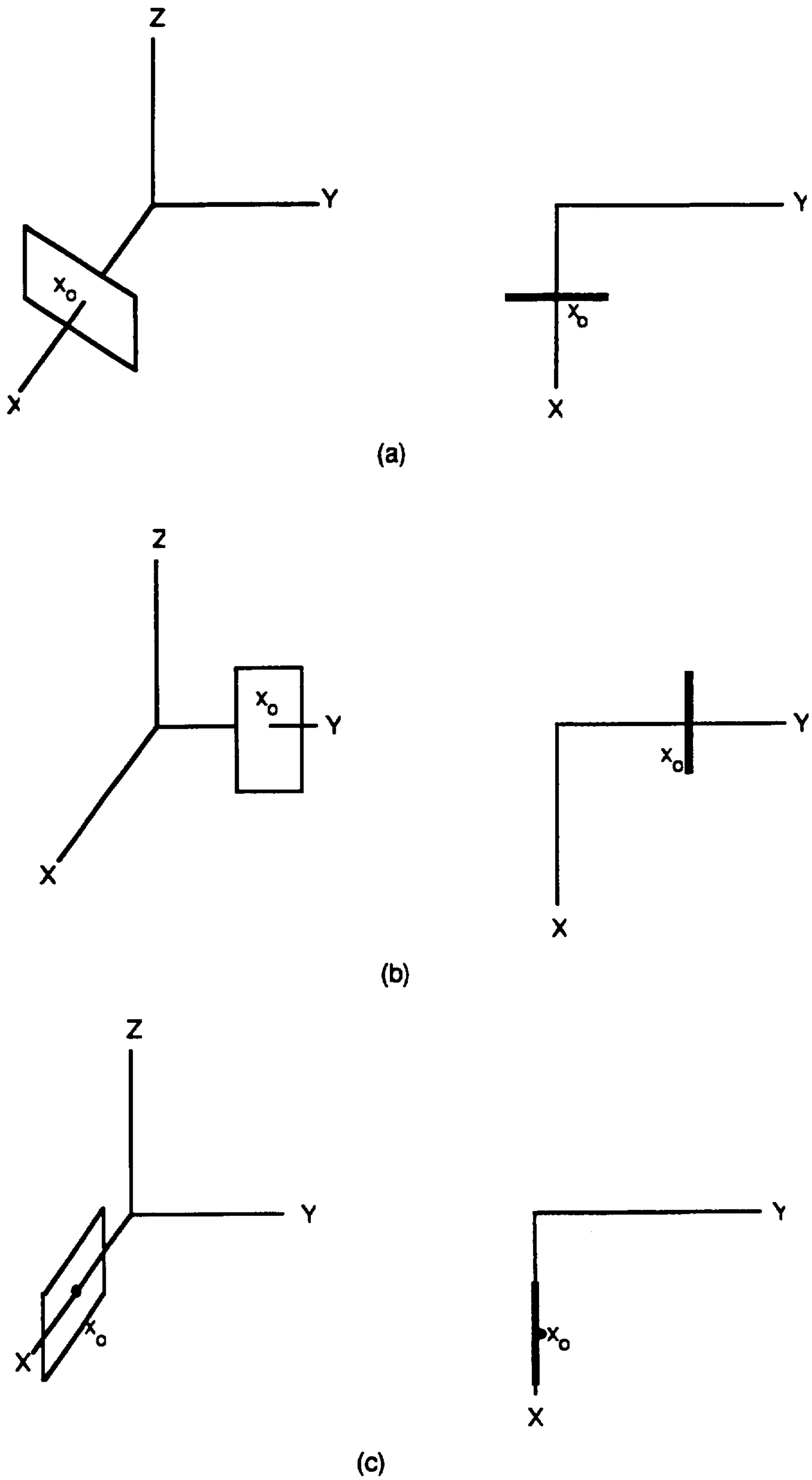

Figure 2.2.3-1. Rotation of a Rectangle About Axes Parallel to the Z Axis.

c. A list of surfaces is displayed. Choose the number of the surface after which you want the new surface to be inserted. Zero inserts the new surface before the first surface.
d. You are then asked for a comment line for the new surface.
e. At this point you have the option of modifying the surface, so that it can be rotated or translated. Follow the instructions in step 7.

12. If you are editing a SOLSHAD file to create a SHADOWV2 or SHADOW version 1.x file, you will be asked for the atomic oxygen surface properties of all the surfaces that previously had only solar surface properties. You will be given the opportunity to view the structure with TECPLOT, change the material name, and enter the surface properties.

13. At this point, you are given the chance to review or modify any surfaces. This is particularly useful if you made a mistake entering the surface properties. If you choose **Y**, then you are returned to the main menu.

14. When finished, choose 7 from the main menu.

15. You then have the option of translating or rotating the entire structure. Enter the menu choice, and then how you much you want the surface rotated or translated.

16. If you chose to rotate or translate, you then have the options of viewing the transformed object, and then undoing the translation or rotation if you desire.

17. You may continue to translate or rotate the entire structure until it is where you want it to be. At this point you have the option once more to review all surfaces.

18. The last section is for the input of various values needed in the calculation. The program displays the current values and asks if you want to modify them. If this is a new file, then the current values are all zero.

19. Enter information for the satellite velocity vector. If you choose to modify the values, you will be asked whether you want to enter them in Cartesian or spherical coordinates. The program then prompts you for x, y, and z components of the velocity (for Cartesian), or magnitude, zenith angle, and azimuth angle (for spherical). See section 2.2.1 for more details. If you are going to use AVESHAD, you need to choose spherical coordinates: enter zero for the magnitude, but correct values for the zenith and azimuth angles; AVESHAD will calculate and replace the magnitude value.

20. Enter information for the following values. (See section 2.2.1 for detailed descriptions). If you plan to use AVESHAD, you can enter 0 for the atmospheric temperature and the average atomic oxygen density.
    Atmospheric temperature.
    Angle of the reference surface.
    Average atomic oxygen density.
    Number of elevation increments for ray aim.
    Number of azimuth increments for ray aim.
    Maximum number of rays per point.
    Random number seed generator.

21. Enter the name of the file to which the data will be written.

22. Program is complete. Exit the window. Return to the Tecplot window (Type **<Cntl><Escape>**. Double-click on **Tecplot**.) Quit. (Type: **/fqq**)

Viewing a TECPLOT Display of the Surfaces

1. Wait until the message "SWITCH TO TECPLOT NOW AND DISPLAY SURFACES" is written. Then type **<Cntl><Escape>**. The box with available windows will appear. Double-click on **Tecplot**.

2. You may get a message saying that there is insufficient memory for the display. If this occurs, click **OK**, and then double-click on the Tecplot icon at the bottom of the screen. (What this means is that when TECPLOT first appears after switching from another window, there will be some extraneous garbage on the screen. However, this will disappear as soon as the screen is refreshed.)

3. Type **<Cntl>p p p<enter>**. This will play a macro called `p.mcr`, which takes the file `mddb.plt` generated by MDDB and plots in on the screen. (If there is extraneous garbage on the screen, this step will eliminate it.) Each of the surfaces will be a different color, and arrows will appear that show which side of each surface is the active side.

   Note: If an error occurs while trying to run `p.mcr`, this may be due to the binary file format generated by the FORTRAN code not being compatible with the TECPLOT version in use. To fix this, replace your copy of `p.mcr` from one of the directories for workstations (`tec5ws` or `tec6ws`, depending on the version of TECPLOT that you are using). Now, when you type **<Cntl>p p p <enter>**, the macro will run the ASCII TECPLOT file through PREPLOT to generate the binary file. (The workstation versions of `p.mcr` will take a little longer to run than `p.mcr`.)

   Also note: If, while trying to run `p.mcr`, no errors occur but the drawing does not look anything like the expected geometry, this can be due to aspect ratio errors that will not show up during the macro run. Quit TECPLOT, edit the file `tecplot.cfg`, make sure the line that contains the aspect ratio is set to 100000. Save the file, restart TECPLOT, and try **<Cntl>p p p <enter>** again.

4. To rotate the object or identify surfaces, see the directions below. If the display appears incomplete, refer to the section on possible problems with TECPLOT.

5. To return to MDDB and continue, type <Cntl><Escape>, and double-click on **MDDB - [Unit *]**.

Note: With Windows 3.1, it is possible to switch back and forth between windows faster by typing <Alt><Tab>. Refer to the Windows manual.

Rotating the Structure in TECPLOT

If the view that TECPLOT gives you is not exactly what you want, it is a fairly simple matter to rotate it. Type the following commands:

/	Get to main menu.
c	Get to Contour menu
v	Get to view menu
r	Rotate
x,y or z	Choose x, y or z axis to rotate about

Now use the mouse or the keyboard arrows to rotate the object. <Esc> will bring you out of rotation mode. If the rotation has moved some parts of the object outside of the field of view, type **v** (for view menu) and then **f** (for fit).

Type **r** to regenerate the picture.

Note: Every time that MDDB generates a new picture for TECPLOT, it reverts back to its original rotation view. To save a particular view, store it as a style sheet. Once you have the view you want, type **/fsw** and the filename (such as `mddb.sty`). To restore this view later on, type **/fsr** <filename>.

Determining Surfaces in TECPLOT

The TECPLOT display shows all the surfaces in different colors so that you can determine which surface on the screen corresponds to which surface in the SHADOWV2 input file. There are two ways to make this determination: displaying a table of colors with the surfaces they correspond to, and individually examining surfaces.

<u>To generate a table, type the following commands:</u>

1. <Cntl>p p table<enter>. (This plays a macro called `table.mcr`.)

2. Wait until the message "Enter total number of surfaces" appears on the bottom of the screen. Press <enter>.

3. Type the total number of surfaces. (This was displayed in MDDB just before transferring to TECPLOT.) Press <enter>.

4. Wait until the message "Place the table" appears at the bottom of the screen. Use the mouse to put the table where you want it. Click with the left button to place it. You can read the table by matching up the color with the number just directly above it. (The one exception is surface #1, which is always at the very bottom of the table.)

<u>To examine surfaces individually, type the following commands:</u>

/	Get to main menu.
c	Get to Contour menu
p	Get to probe menu
e	Examine
n	Nearest Point *(This command not needed for TECPLOT version 5)*

Now use the mouse to place the crosshairs on the region of interest. Click with the left mouse button. A table will appear on the left side of the screen. The second value in the table corresponds to the surface number. (If you get a non-integer number, it is because you have clicked on an arrow instead of a real surface.) To get out of examine mode, hit <escape>. To get rid of the crosshairs, regenerate the screen (/cr).

Possible Problems

A minimum number of grids are required for certain shapes: for example, you cannot create a disk with only 2x2 grids. The second grid value must be at least 3 for TECPLOT to approximate the disk by a triangle; use a value of 8 or more to get anything remotely circular.

TECPLOT has difficulty with mesh units that come to a point, and it will generally not draw them. To avoid this problem, do not use values of zero for ratios in the trapezoid, disk, and cone geometries. Instead, use ratios that are very small (0.001) to approximate triangles (ratio of trapezoid short size to long side), disks with no holes in the center (ratio of inner radius to outer radius), and cones that come to a point (ratio of small radius to large radius). Other coordinates may have to be modified slightly if you are concerned about geometries overlapping. Similarly, spheres' polar angular extent should range from 0.001 to 179.999 instead of 0 to 180 degrees. If you choose not to add this small factor of 0.001, SHADOWV2 will still perform the calculations correctly, but the TECPLOT display may be incomplete, both during input file generation, and during the final display of atomic oxygen flux.

Some versions of TECPLOT will have some graphical conflicts with some versions of Windows. If the screen appears abnormal when returning to TECPLOT from another Windows application, **<cntl> r** will refresh the screen.

TECPLOT will occasionally have other quirks as well. Sometimes mesh lines are missing or are drawn where they shouldn't appear. In general, rotating the view to something slightly different will correct these problems.

2.2.4 Calculating the Averaged Values

The mission file generated by the direct atomic oxygen program (FLUXAVG) contains all the data calculated for a complete mission as a function of time. However, SHADOWV2 does not calculate flux or fluence as a function of time; instead it calculates the flux on the various surfaces that has been averaged over a time period. This period is known as the "event." For example, your mission may run from Jan 15, 1994 to Jan 15, 1995, and you may want to know what the average flux was on your structure during the second month in orbit. The event start and end dates then would be Feb 15, 1994 and Mar 15, 1994. A program called AVESHAD has been constructed to take a mission file and then to calculate the values for atomic oxygen number density for the atmosphere, temperature of the atmosphere, and satellite velocity relative to the atmosphere, averaged over the event period. AVESHAD then asks for a SHADOWV2 input file, substitutes the new calculations into that file, and stores it as a new SHADOWV2 input file.

Installation of AVESHAD. AVESHAD is written in ANSI C, and can be run either on a PC, a workstation, or on the mainframe computer where the mission file was generated. To install it, follow these instructions:

1. Create a directory called AVESHAD. (In DOS or Unix, type **mkdir aveshad.**)
2. Change to that directory. (In DOS or Unix, type **cd aveshad.**)
3. For a PC, copy the file AVESHAD.EXE. For a Macintosh, copy the file AveShad. For a mainframe or workstation, copy the source files (aveshad.c, calcDen.c, createIn.c, dateDiff.c, and linear.c), and compile them with the local C compiler. This may require the math library option `-lm`.
4. Copy a mission file and a SHADOWV2 input file to the AVESHAD directory.
5. Start AVESHAD by typing **aveshad**. (Or, for the Macintosh, double click on the AveShad2.0 icon.)

Running AVESHAD. AVESHAD begins by asking for the mission file name. Then it asks for the event start and end dates in the following format:

MM DD YYYY HH MM SS.SS

which stands for month, day, year, hour, minute, and seconds (to two decimal places). It is not necessary to use two digits for numbers less than 10 (for example, "1" will do as well as "01"), but the year must contain all four digits. The event start and end dates must be within the mission file start and end dates; these dates are listed near the beginning of the mission file.

The program then reads through the mission file and calculates the average oxygen number density, temperature, and satellite velocity, and prints these to the screen. (The details of this calculation are described in sec. 3.2.3) It then asks for the original and new SHADOWV2 input file names. The new input file will be identical to the old, except that the calculated averaged values will be substituted in for the existing values, and the first four lines will contain the event description, the start date, the end date, and the mission file name.

AVESHAD will only calculate the the magnitude of heading velocity. Therefore, the heading velocity data must be entered in spherical coordinates (VECTIN=F), where the zenith and azimuth angles should be already determined and entered into the SHADOWV2 input file using either MDDB or a text editor.

Be sure to use AVESHAD version 2.0 with SHADOWV2 files, and version 1.0 with SHADOW version 1.x files.

2.3 INSTALLATION AND OPERATION OF THE MICROENVIRONMENT AO EXPOSURE PROGRAM

This section describes installation and operation of SHADOWV2 on the CONVEX computer on which it was developed, and gives some suggestions for migrating SHADOWV2 to other computers.

2.3.1 Installation on a CONVEX Computer

SHADOWV2 was developed on a CONVEX C2 supercomputer running under CONVEX operating system release 9.0 and CONVEX version 4.2bsd unix. SHADOWV2 is written in CONVEX FORTRAN. This section describes the installation and operation on a machine identical to that on which it was developed. It is suggested that a directory called microenv2 and one subdirectory called shadowv2 be created, and that all files be put into these directories.

All files for SHADOWV2 reside on directory microenv2 and its subdirectory microenv2/shadowv2. Subdirectory microenv2/shadowv2 contains FORTRAN source code for program SHADOWV2 and its subroutines as well as a Makefile for building the SHADOWV2 executable. These files are listed in tables 2.3.1-1 and 2.3.1-2, respectively.

Follow the procedure below for loading SHADOWV2 and preparing it to execute. In this procedure, **bold** text indicates commands the installer should type. Press return after each command. Remember that the unix operating system is case sensitive.

Note: Users of SHADOW version1.x (ref. 2) will note that SHADOWV2 and SHADOW version1.x share a number of subroutine names in common. Although their names are the same, these subroutines are different and can not be interchanged between the two codes.

1. Create and load the directory microenv2 with the files given in table 2.3.1-1 and subdirectory microenv2/shadowv2 with the files in table 2.3.1-2.

2. Get to subdirectory microenv2/shadowv2 by typing **cd** /pathname/**microenv2/shadowv2**, where pathname is the appropriate path.

3. Type **make**. This causes the file Makefile to be run, compiling all FORTRAN routines in the subdirectory and creating an executable called shadowv2.x.

4. Type **cp shadowv2.x ..** to copy the executable to microenv2.

5. Get to directory microenv2 by typing **cd ..**

6. Edit file run.shadow to change the lines
   shadowv2.x < shadowv2.in_sample >! shadowv2.out_sample
   to
   shadowv2.x < shadowv2.in_sample >! test.out
   and
   mv TAPE7 shadowv2.tp7_sample
   to
   mv TAPE7 shadowv2.tp7_test

7. Change the path in the first line to the proper path. Save and exit.

8. Ensure that run.shadow has execute permission by typing **chmod +x run.shadowv2.**

9. Run the sample test case by typing **run.shadowv2**. The sample test case takes about 6 minutes CPU time. When the run is complete, compare file shadowv2.out_sample with test.out and shadowv2.tp7_sample with shadowv2.tp7_test. These files should give the same results.

Table 2.3.1-1
Files in the Directory microenv2

run.shadowv2*	shadowv2.out_sample	shadowv2.x*
shadowv2.in_sample	shadowv2.tp7_sample	

Table 2.3.1-2
Files in the Directory microenv2/shadowv2

Makefile	cwb.f	fluxint.f	packer.f	rg1err.f
acosd.f	cwb2.f	gendfdw.f	prnote.f	shadowv2.f
asind.f	cwb2int.f	hsphere.f	rayg1.f	store.f
atan2d.f	cwbint.f	intflux.f	rayg2.f	swapn.f
autovis.f	cwbsc.f	iquad.f	rayg3.f	switch.f
bflux.f	diffuse.f	les.f	rayg4.f	unitize.f
connec.f	dl.f	lquad.f	refdf.f	
cross.f	dot.f	multi.f	reflect.f	

2.3.2 Running the Microenvironment AO Exposure Program

Before running SHADOWV2, build its input file describing your geometry and operating conditions using MDDB and AVESHAD (per sec. 2.2). Edit the run.shadowv2 file in the microenv2 directory to direct your program input file to standard input and to direct standard output to your output file. You may also wish to direct TAPE7, the file containing information for displaying the atomic oxygen exposure in TECPLOT, to a different file name. Every time SHADOWV2 is run, any existing version of TAPE7 is overwritten. SHADOWV2 may be run interactively by typing **run.shadowv2** or in batch mode by typing **qsub -q v run.shadowv2** where v is the queue to which the job is to be sent. Because SHADOWV2 may take significant execution time, running in batch mode is recommended.

As written, SHADOWV2 is set to allow up to 100 surfaces, 5000 nodes, and 10000 solid angle bins per node for ray aiming. These dimensions are set by PARAMETER statements in the FORTRAN code. Table 2.3.1-3 summarizes these parameters and what they affect. Users who do not run cases which need these large dimensions may find that SHADOWV2 runs more quickly if they are reduced.

2.3.3 Some Information for Installation on Other Computers

This section provides information about SHADOWV2 which will be useful if SHADOWV2 is to be converted to run on computers other than the CONVEX described in section 2.3.1.

SHADOWV2 is written in mostly ANSI standard FORTRAN and generally does not call functions specific to any particular operating system or FORTRAN compiler. However, the following exceptions are noted.

Calls are made to CONVEX lveclib8 cpu elapsed time function CPUTIME in program SHADOWV2. This function must be changed to the proper function name for other systems, or, references to it may be deleted without significant effect on program execution. CPUTIME is used to output elapsed cpu time at various stages of SHADOWV2.

RAN is a CONVEX lveclib8 VAX-like random number generator. The appropriate random number generator call must be substituted in subroutines DIFFUSE, MULTI, and RAYG4. Also, the random number seed initialization must be made proper for the random number generator used. RAN uses a large integer number as a seed. RAN generates uniformly distributed random numbers between 0 and 1.

Numerous seven-character variable and subroutine names are used in SHADOWV2. If the compiler requires ANSI standard six character names, the names can be truncated to six characters without causing duplicate variable or subroutine names.

SHADOWV2 is compiled to run using CONVEX double-precision word length (8 bytes or 64 bits) for all real variables. This word length is needed to maintain numerical accuracy. Real variables in FORTRAN routines in microenv2/shadowv2 are not declared double precision explicitly, but are converted to double precision with a FORTRAN compiler option. Users converting SHADOWV2 to run on other computers should be aware that single precision word length (4 bytes or 32 bits) real variables may not give the same numerical accuracy as double-precision word lengths.

Table 2.3.1-3
Parameters in SHADOWV2

PARAMETER	Value	Appears in COMMON Block	FORTRAN Routines Affected	PARAMETER usage
MAXPS	100	//, /LOGI/, /NVS/, /RNODE/, /RTR/, /SEE/, /SURF/, /SURFC/,	AUTOVIS, CONNEC, FLUXINT, HSPHERE, MULTI, RAYG1, RAYG2, RAYG3, RAYG4, REFDF, SHADOWV2	Maximum number of surfaces.
MAXNOD	5000	//, /FLX/, /LOGI/, /RNODE/, /RTR/, /SEE/	AUTOVIS, CONNEC, CWB2INT, FLUXINT, HSPHERE, MULTI, RAYG1, RAYG2, RAYG3, RAYG4, REFDF, SHADOWV2	Maximum number of nodes.
MAXID	3*MAXNOD	//	AUTOVIS, CONNEC, FLUXINT, HSPHERE, MULTI, RAYG1, RAYG2, RAYG3, RAYG4, REFDF, SHADOWV2	Dimension of ID array.
MAXBIN	10000		HSPHERE, SHADOWV2	Maximum solid angle bins into which rays will be aimed for each node.
MAXID2	2*MAXNOD	//	FLUXINT	Scratch array dimension.

Notes:
- All FORTRAN routines are in files of the same name in lower case with a .f extension.
- All files are are in directory microenv2/shadowv2.

The following CONVEX FORTRAN compiler options are either recommended or mandatory when compiling SHADOWV2:

-or all	Provides full optimization report (recommended).
-O2	Optimize code with vectorization (recommended).
-pd8	All default integer, logical, real, and double precision values occupy 8 bytes of storage (mandatory).
-rl	Perform loop replication optimizations (loop unrolling, dynamic code selection) when profitable to do so (recommended).
-72	Process only the first 72 characters of each line. Lines containing tab characters will not compile properly with this option (mandatory).

2.4 OUTPUT: 3D Plot Generation

2.4.1 Plot Generation

SHADOWV2 generates an ASCII file that can be read by TECPLOT to display the structure with colors on its surfaces that correspond to the different levels of atomic oxygen flux. This file is named TAPE7, unless otherwise renamed in the batch file. In order to handle the large range of fluxes that can vary over 30 orders of magnitude, the output file contains values of $\log_{10}$(flux), where the flux units are atoms/cm^2-s. First the ASCII file must be converted into a binary file for input into TECPLOT, using a program called PREPLOT. Then a macro can be run to display the surface. Finally, TECPLOT commands can be used to rotate, add text, print, extract data, etc.

For complete instructions on what can be done in TECPLOT, read the software manual. This section contains instructions on how to do the most common tasks for viewing the SHADOWV2 output, using a PC. To get started, follow these instructions:

1. Change directory to where TECPLOT is located. (Generally, **cd \tecplot.**)
2. Type **preplot <filename.xxx>**, where <filename.xxx> is the TECPLOT file generated by SHADOWV2. PREPLOT converts the file into binary, and names the new file <filename.plt>.
3. Type **tecplot** to start up TECPLOT.
4. Load the data file. (Commands: **f d r**. Type in the file name with **.plt** extension.)
5. Run the macro `shadow.mcr`. To do this type **<cntl>p p shadow**. The structure will appear, although it may be difficult to see various parts of it due to the positioning of the x, y and z axis.

2.4.2 Plot Manipulation

Rotating the Structure

Type the following commands:

/	Get to main menu.
c	Get to Contour menu.
v	Get to View menu
r	Rotate.
x,y or z	Choose x, y or z axis to rotate about.

Now use the mouse or the keyboard arrows to rotate the object. **<Esc>** will return bring you out of rotation mode. If the rotation has moved some parts of the object outside of the field of view, type **v** (for View menu) and then **f** (for Fit).

Type **r** to regenerate the picture.

Adjusting the Colors and Adding a Color Table

TECPLOT will automatically choose a color scale, based on the highest and lowest values of the atomic oxygen flux. In general, this scaling is good, but sometimes a small number of nodes will have extreme values that will throw off the scale. To adjust the color scale, type the following commands:

/	Get to main menu.
c	Get to Contour menu.
c	Get to Contour Value menu.
l	Levels.
n	New Range.
n	New Minimum and Maximum.

Choose a number of levels. (15 is a good value.) Enter the minimum. Enter the maximum. Type **<cntl>r** to regenerate the picture. Redo the steps from "New Range" to adjust until you get a good set of contours.

To add a table that shows which colors correspond to which levels, type the following:

/	Get to main menu.
c	Get to Contour menu.
c	Get to Contour Value menu.
t	Table.

In this menu, you may adjust the text fonts and colors, the spacing in the table, and whether you have a bar outline. Finally, type **p** to place, and use the mouse to put the table where you want it to be. Click the mouse to finalize the table location.

Plotting Specific AO Fluxes

The total AO flux on a surface can be divided into primary flux, specularly-reflected flux, diffusely-reflected flux, and the flux striking the surface may be removed from further consideration by recombination or surface reaction. It is possible to view the structure looking only at exposure from a single one of these groups. Table 2.4.2-1 shows the variable numbers and names that correspond to the AO fluxes.

Table 2.4.2-1
TECPLOT Variable Numbers and Names

Variable number	Variable name	Value
1	NODE	Node index
2	PRIM	Primary AO flux on surface
3	SPEC	Specularly-reflected AO flux on surface
4	DIFF	Diffusely-reflected AO flux on surface
5	RECOMB	AO flux at surface removed by recombination
6	REACT	AO flux at surface removed by surface reaction
7	TOTAL	Sum of primary, specularly-reflected and diffusely-reflected AO flux
8	X	x-coordinate
9	Y	y-coordinate
10	Z	z-coordinate

Type the following commands:

/	Get to main menu.
c	Get to Contour menu.
c	Get to Contour Value menu.
v	Get to the Variable menu

Use arrows to choose a AO flux group. Press enter

<esc>	Get to Contour menu
r	Regenerate the image

Style Sheets

A style sheet contains all the information as to how a data file is displayed. It can be used on the data that it was generated with or on new data that is similar in format. To save or restore a style sheet, type the following

/	Get to main menu.
f	Get to File menu.
s	Get to StyleSheet menu.
w or **r**	Write or Read.
filename	Filename that ends with `.sty`.

Printing

Type the following commands:

/	Get to main menu.
f	Get to File menu.
p	Get to Print menu.

In this menu, you may adjust the paper size and orientation, the device configurations, the printer format, number of copies, the file path for hardcopy files, and where to route the output. When done, type **g** for GoPrint. Now you can position and scale the picture. Again, type **g** for GoPrint when done, and the print will be made.

Probing Data

TECPLOT allows you to pick a spot on the surface and get the exact exposure value there. Type the following commands:

/	Get to main menu.
c	Get to Contour menu.
p	Get to Probe menu.
e	Examine.
i	Interpolate *(This command not needed for TECPLOT version 5)*

Use the mouse to place the cursor where you want the exposure value. Click with the left button. A table appears on the left side of the screen. You can read off the values next to the variable numbers. (See table 2.4.2-1 for an explanation of these numbers.) You can continue clicking on new points. Press esc or right mouse button when done.

Extracting Data

TECPLOT allows you to draw a path across your surface, extract the atomic oxygen flux numbers, and generate a 2D plot of flux versus distance. Type the following commands:

/	Get to main menu.
c	Get to Contour menu.
p	Get to Probe menu.
x	Extract data.
l	Line *(This command not needed for TECPLOT version 5)*

Use the mouse to place the cursor at the beginning of the path. Click with the left button. Move the mouse to the end of the first line segment. Click with the left button again. Continue until you get to the end of the path. Then click the right mouse button. Enter **y** to accept the polyline, or **n** to redo it. Enter **y** for extra distance variable, if asked. Enter the number of points for your x-y curve. Enter a filename and a header.

A new file has been created with this data. You can look at it by loading the new file. (Commands: **/ f d r**. This new file will be automatically inserted as the default name. Plot it as an X-Y plot. (Commands: **/ x**.) Adjust the x and y axis variables (Commands: **a x** and **a y**.) to be the DIST and TOTAL variables. Remove any extraneous y-axis variables. (Command: **r**.) **<cntl> r** to refresh the screen.

3.0 TECHNICAL FEATURES OF THE COMPUTER MODEL

3.1 PROGRAM FLOWS

3.1.1 Program Flow for the Microenvironment AO Exposure Model

Figure 3.1.1-1 shows the SHADOWV2 block diagram. The names of major subroutines in the block diagram are given in parenthesis. Figure 3.1.1-2 is a subroutine tree for SHADOWV2 and shows all subroutines and functions and their calling hierarchy. This section describes the general order of program execution; details of the algorithms used are given in section 3.2.1.

SHADOWV2 starts execution by echoing its input file to output. The input file is then rewound and the mission description (start and end dates and mission file name) is read. Subroutine RAYG1 reads the geometry definition and surface properties for all surfaces, sets up the grid of nodes for each surface and other quantities needed for ray tracing, and calculates the area of each node.

The atomic oxygen flux from any direction measured from the satellite heading (ram) direction is a function only of the zenith angle measured from ram. Because subroutine GENDFDW uses a rather lengthy procedure, it is impractical to calculate the directional flux (the flux per steradian from a given direction) directly for each ray. Instead, GENDFDW calculates a table of directional fluxes at 1-degree intervals from parallel to ram to 180 degrees from ram. The directional fluxes per steradian along each ray are interpolated from this table.

Subroutine INTFLUX calculates the flux on a hypothetical unshielded reference surface whose surface normal is oriented at a user selected angle from the ram. The calculation is done by integrating the directional flux over the half sphere above the surface using Simpson's rule.

A number of quantities used in later calculations are precalculated and stored. SHADOWV2 precalculates many quantities which are used repeatedly to speed up execution.

All surfaces have previously been divided into a grid of nodes by subroutine RAYG1. SHADOWV2 defines a set of points at which fluxes will be calculated so that nearly the entire surface is covered. This grid for fluxes has points at one corner (call it the lower left) of each node plus points in the lower right corner of the right most column of nodes, at the upper left of the topmost row of nodes, and in the upper right corner of the upper right node. Each point is set in 1% of the node size from the nearest edge of the node. This gives nearly full coverage of the surface and avoids any ambiguity as to which node the point belongs to. The coordinates of each grid point, both in Cartesian (x, y, z) space and in internal node coordinates, are saved for future use.

Subroutine AUTOVIS calculates a visibility matrix for the surfaces defining the geometry of the object. The visibility matrix indicates which surfaces can be shielded by themselves or other surfaces, or can reflect atomic oxygen flux to other surfaces or to themselves. The visibility matrix is analyzed to determine which, if any, surfaces have flux reflected to them by any surface. This information is used to speed up program execution in two ways. First, when surfaces are being checked to see if a ray to or from them will be blocked by any surface, only those surfaces which can see the first surface need be checked. Other surfaces can be ignored. Second, if a surface cannot have flux reflected on to it, there is no need to ray trace reflected flux from that surface.

SHADOWV2 BLOCK DIAGRAM

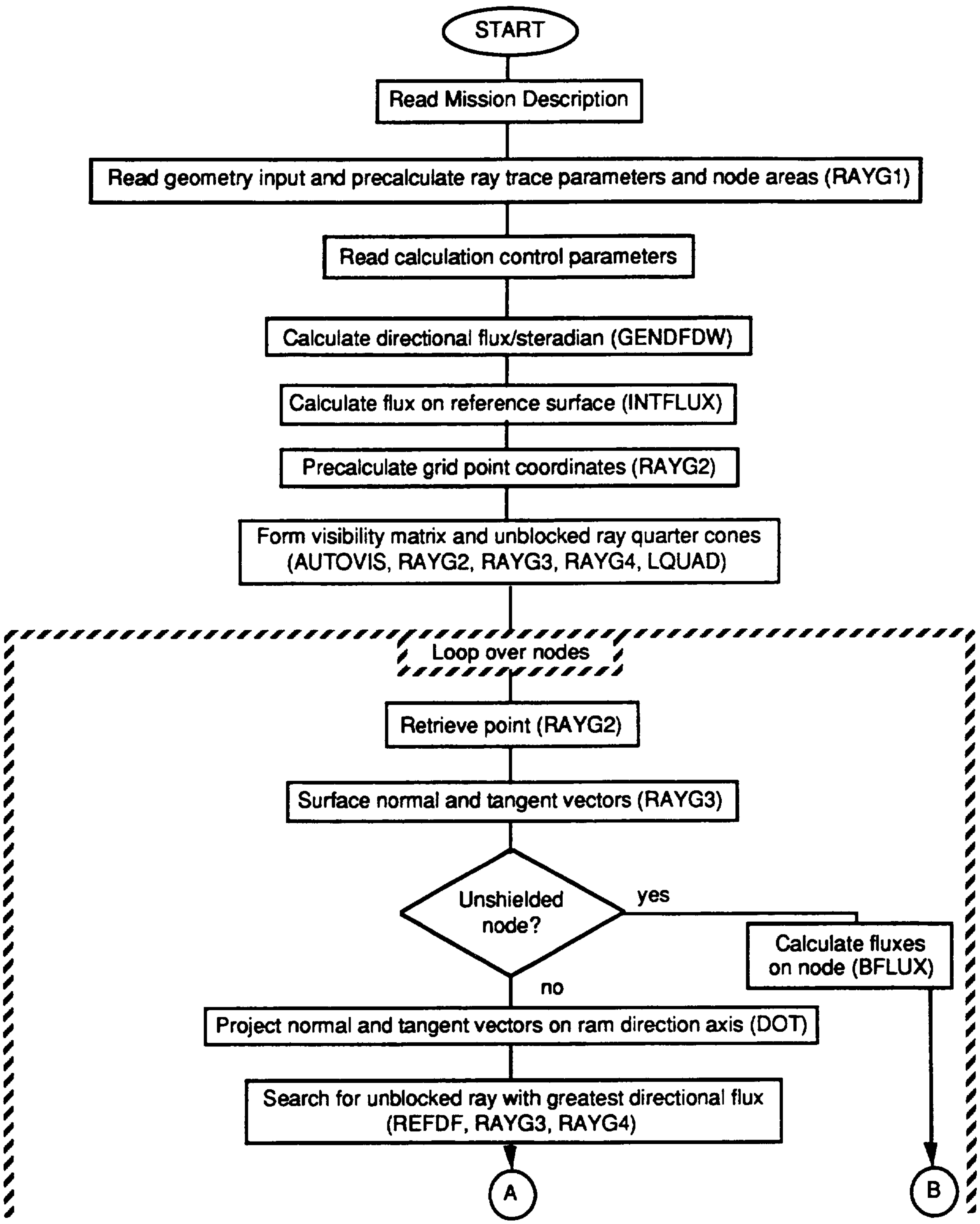

Figure 3.1.1-1. SHADOWV2 Block Diagram (Sheet 1 of 3).

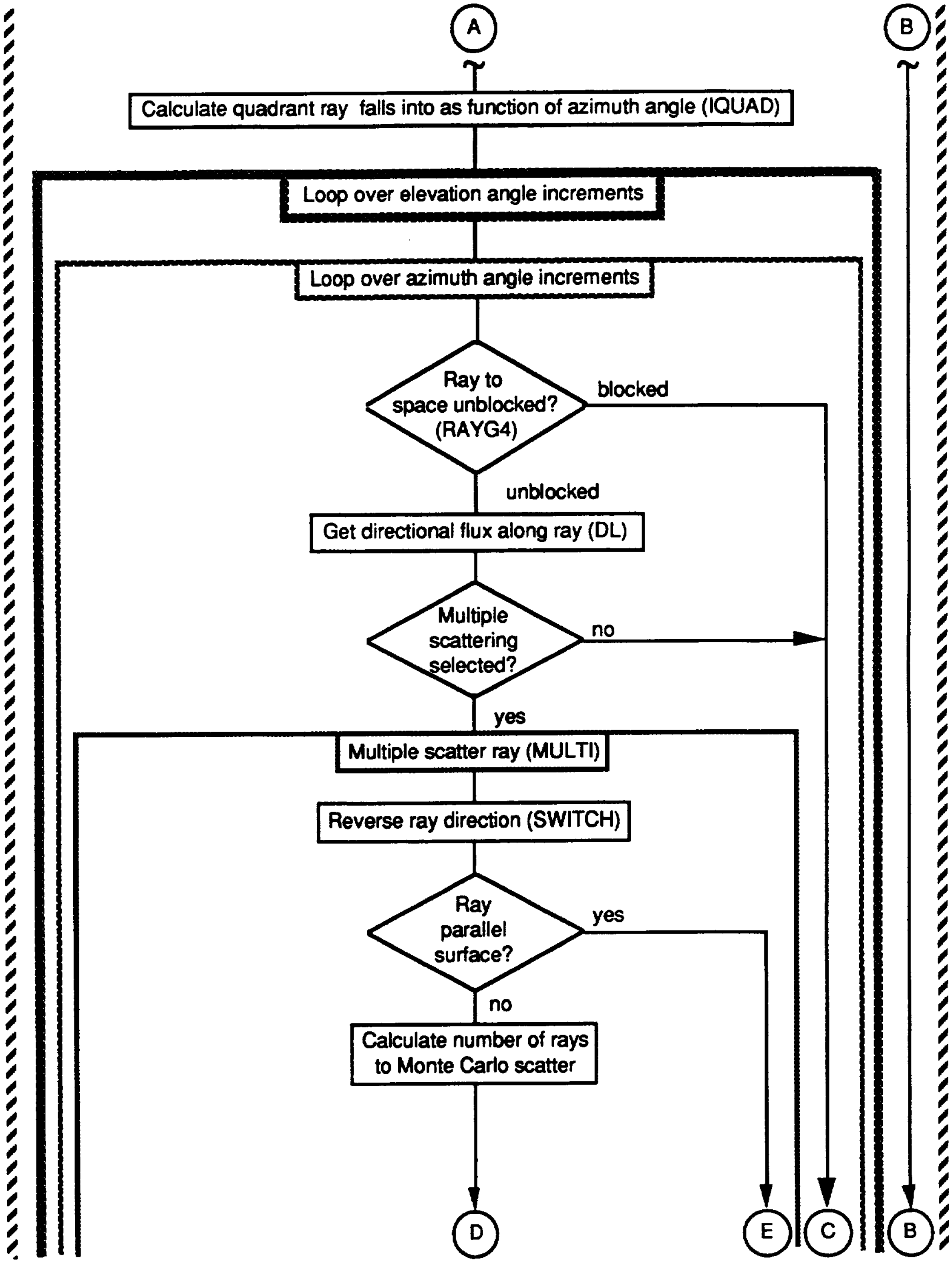

Figure 3.1.1-1. SHADOWV2 Block Diagram (Sheet 2 of 3).

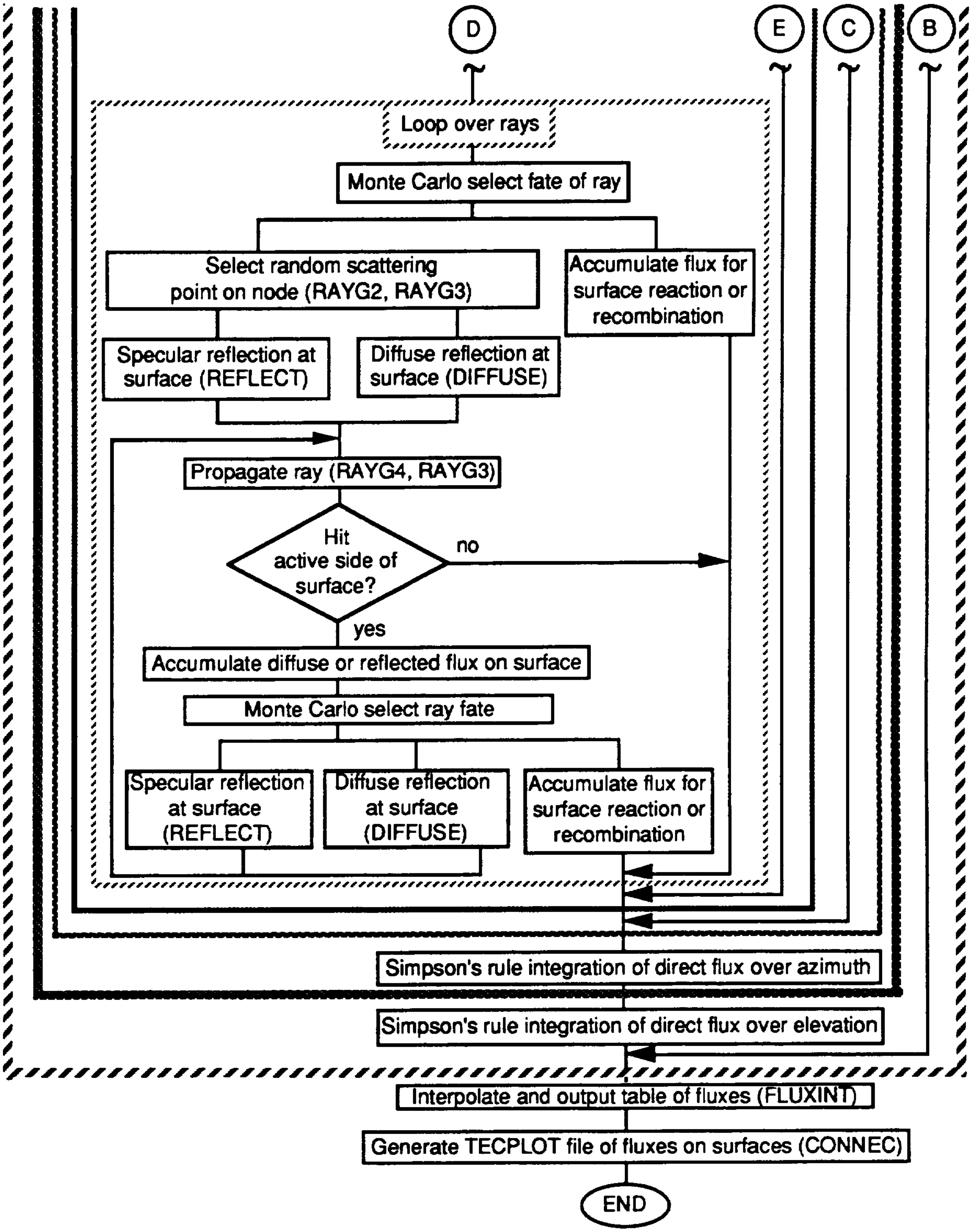

Figure 3.1.1-1. SHADOWV2 Block Diagram (Sheet 3 of 3).

SHADOWV2 Subroutine Tree

- SHADOWV2
  - PRNOTE
  - RAYG1
    - RG1ERR
  - UNITIZE
  - ACOSD
  - ATAN2D
  - GENDFDW
  - INTFLUX
    - DOT
    - ACOSD
  - RAYG2
  - AUTOVIS
    - RAYG2
    - RAYG3
    - STORE
    - SWITCH
    - UNITIZE
    - DOT
    - LQUAD
    - RAYG4
      - RAYG3
  - RAYG3
  - BFLUX
  - DOT
  - CROSS
  - SWITCH
  - SWAPN
  - STORE
  - REFDF
    - DOT
    - ACOSD
    - IQUAD
    - STORE
    - RAYG4
      - RAYG3
    - CROSS
    - UNITIZE
    - SWITCH
  - IQUAD
  - RAYG4
    - RAYG3
  - DL
  - MULTI
    - SWITCH
    - DOT
    - RAYG2
    - RAYG3
    - REFLECT
    - DIFFUSE
    - IQUAD
    - SWAPN
    - RAYG4
      - RAYG3
  - HSPHERE
  - FLUXINT
    - PACKER
    - CWB2
      - CWBSC
      - CWB
    - CWB2INT
      - CWBINT
      - CWB
  - CONNEC
    - LES

Figure 3.1.1-2. SHADOWV2 Subroutine Tree.

The visibility matrix is calculated by ray tracing from each point on every surface to every other point and ray tracing along the surface normal from the active side of the surface at each point. The process is sped up by noting that plane surfaces (trapezoids and disks) and the positive sides of cones, cylinders, and spheres can never reflect onto themselves. During this ray tracing, rays which hit the inactive sides of surfaces are flagged. Such rays often indicate that the object geometry is not properly constructed and that surfaces may be exposed to atomic oxygen which were not intended to be exposed.

Experience has shown that very often when one surface may be shielded by another, the shielding surfaces are not directly above the shielded surface, but off to the side. If the maximum angle from the surface normal for which a surface is unshielded is known, rays from the surface at lesser angles are unblocked to space and raytracing need not be done to test for blockage. Further, rays leaving the surface at angles greater than the maximum angle may be blocked by other surfaces. Raytracing is required to test for blockage of these rays. While calculating the visibility matrix, AUTOVIS tabulates and stores the maximum angle for unblocked rays in each of four quadrants, where the four quadrants are with respect to the perpendicular tangent vectors to the surface at the point of interest. The tangent vectors are calculated by RAYG3.

At this point, SHADOWV2 is ready to start calculating the atomic oxygen flux on the nodes of the surfaces of the object. The calculation procedure is the same for each node. First subroutine RAYG2 is called to retrieve the coordinates of the point at the center of the node and then subroutine RAYG3 is called to generate the surface normal and the tangent vectors at the point. If the back side of the surface is active, the normal vector is reversed and the tangent vector directions are adjusted to ensure a right-hand coordinate system such that tangent vector 1 cross tangent vector 2 equals the surface normal vector. Note that all direction vectors are generated as unit vectors, which eliminates the need for a separate normalization step. The surface normal and tangent vectors are projected on to the ram direction.

The surface is checked to see if it is unblocked by any other surface. If so, the flux on the node can be calculated directly by function BFLUX and the more involved calculation for shielded surfaces described below need not be done.

If the node can be shielded by another surface, the surface normal and tangent vectors are projected on to the ram direction. Subroutine REFDF is called to determine the direction from which the point receives the largest primary directional flux. This direction is used to scale the number of rays of flux which will be Monte Carlo scattered for flux arriving at the point from other directions. The direction of maximum directional flux on the point is determined by ray tracing in the ram direction to see if a ray to space is unblocked. If blocked, rays are traced along cones of increasing half angle centered on the ram direction until a ray to space is found.

The half sphere above the point on the object is divided into a grid of equal increments in zenith angle and in azimuth angle as shown in figure 3.1.1-3. Rays are traced through each point on the grid in a systematic manner. Because this angular direction grid is used for every point, execution efficiency has been gained by precalculating and storing the sines and cosines of the spherical coordinate angles specifying the points on the grid. Ray tracing over the grid takes place by stepping over all azimuth angle points for a fixed zenith angle starting at the first zenith angle greater than 0 degrees and ending at the last less than 90 degrees. Zero and 90 degree zenith angles are skipped because neither contributes to the flux on the surface, 0 degrees because the element of solid angle is zero, and 90 degrees because the cosine of the angle between the flux direction and the surface normal is zero. The primary direct flux on the surface is calculated by calculating the directional flux at each azimuth grid point for fixed zenith angle and then stepping the zenith angle. The integration of directional flux over solid angle to obtain the primary flux at the point on the surface is done in two steps: first, a Simpson's rule integration over azimuth angle at each zenith angle and then a Simpson's rule integration over zenith angle.

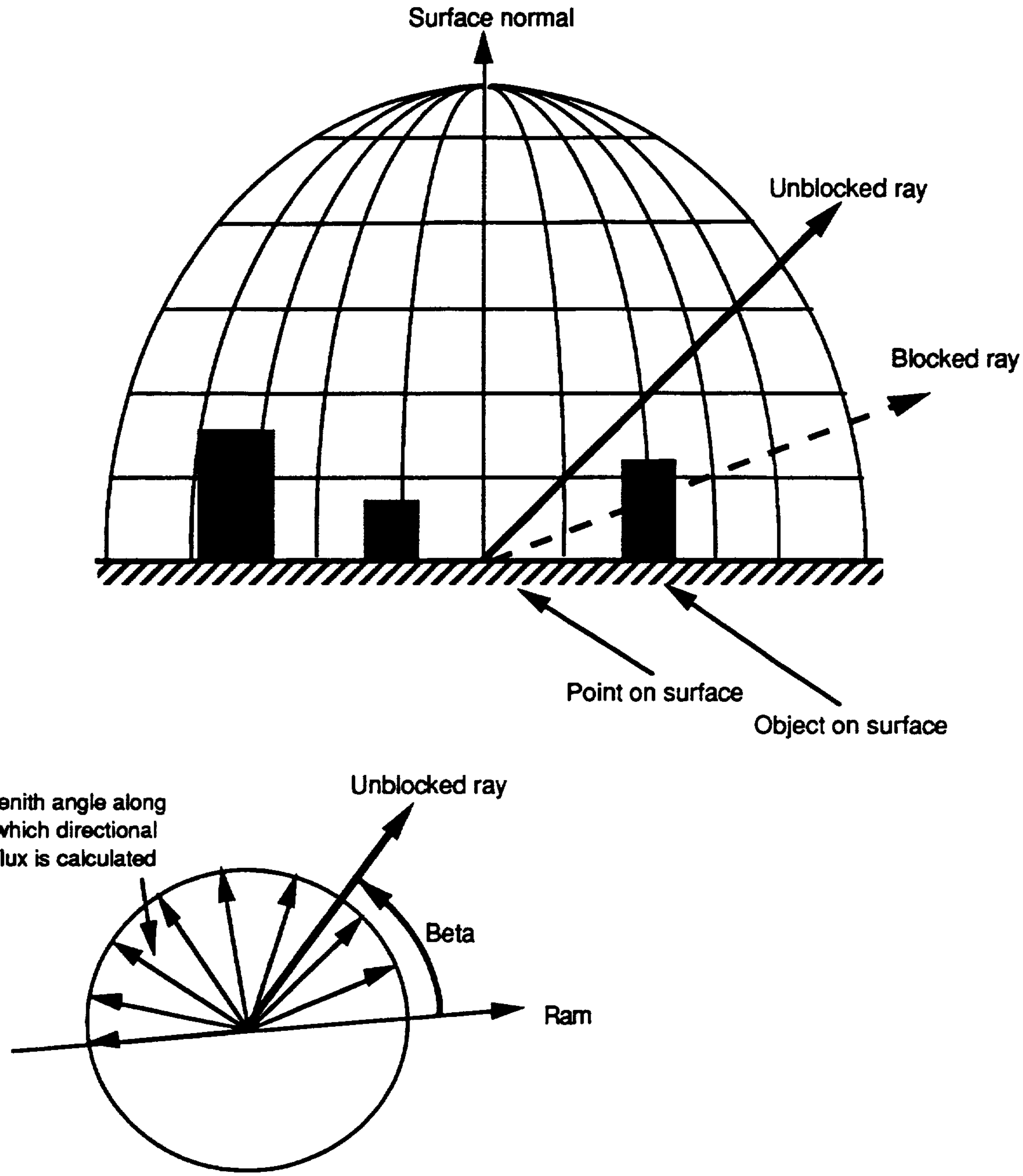

Figure 3.1.1-3. Ray Tracing Geometry.

The preliminaries to ray tracing the primary flux having been described; a few words about the program flow for ray tracing of primary and scattered atomic oxygen flux are in order. This description applies to ray tracing along a fixed zenith and azimuth direction in the half sphere over a point on the surface. First, the ray direction is checked to see if it is unblocked to space. If the ray may be blocked, subroutine RAYG4 is called to determine if the ray is blocked by any surface.

Blocked rays are given no further consideration. If the ray is unblocked, the angle beta between the ray direction and ram is determined (fig. 3.1.1-3) (the directional flux depends only on this angle) and the directional flux along the ray is interpolated by four-point Lagrange interpolation. The primary directional flux at the point is logged for later integration to give the total primary flux at the point. If multiple scattering is selected, subroutine MULTI is called to handle this.

The number of rays to Monte Carlo scatter from a node is determined as the number of rays per average node area times the ratio of the node area to the average node area times the cosine of the angle between the surface normal and the ray direction times a scale factor dependent on the directional flux along the ray on the node and the maximum directional flux on the node. This ensures that each surface is illuminated with the same areal density of AO flux rays. The scattering procedure is the same for each scattered ray.

For each scattered ray, subroutine MULTI reverses the direction of the ray so that it is directed toward the center of the node rather than to the space. A check is made to see if the ray is parallel to the surface or very nearly so. If it is, the ray is given no further consideration; the ray tracing routine has difficulty handling such rays properly and, in any event, they contribute only a very small flux. Rays not parallel to the surface are Monte Carlo scattered by the following procedure.

A ray of atomic oxygen flux striking a surface may undergo one of four fates: specular reflection, diffuse reflection, surface reaction, or recombination with another atomic oxygen to form O_2. In the event of the latter two fates, propagation of the ray stops and the flux due to the fate is accumulated. The fate of a ray is determined by a Monte Carlo (random) selection in which the probability of selection is proportional to the surface property value of the fate. The surface properties sum to one, so one of the four fates is guaranteed to be selected.

If reflection is selected, a random point on the node is chosen and its coordinates, surface normal, and tangent vectors are calculated by RAYG2 and RAYG3. For nonplanar surfaces, the surface normal is a function of position on the surface and the tangent vectors may also be functions of position. Choosing random positions on a node for reflecting AO flux ensures that surfaces which are exposed to reflected flux receive the proper exposure independent of their area or orientation with respect to the ray direction.

If specular reflection is selected, the normal component of the ray is reversed to give the reflected ray. Diffuse reflection has a probability of scattering uniform in cosine of zenith angle measured from the surface normal and uniform in azimuth angle. These two angles are chosen randomly and the ray is directed along them. Subroutine RAYG4 propagates the reflected ray and determines whether it strikes the active side of a surface or not. If the ray does not strike the active side of a surface, consideration of that ray is terminated. If the ray does intersect the active side of a surface, subroutine RAYG4 determines the location (node) on the surface and subroutine RAYG3 determines the surface normal and tangent vectors at the intersection. The specular or diffuse flux at this point is assigned to the node and accumulated there. The ray itself is Monte Carlo scattered from the point of intersection on the node and propagated or terminated in the same manner as for the initial scattering. This process continues until the ray is removed from consideration or until a maximum of 100 scatters has occurred.

When all of the AO flux calculations have been completed, the fluxes have been calculated at the center of each node on the structure. Because it is desirable to have the fluxes represented at the corners of the nodes for graphical display and tabular output, the fluxes at the centers of the nodes are interpolated to the points at the corners of the nodes. After interpolation, SHADOWV2 generates a table of primary, specular reflected, diffuse reflected, surface reaction, recombination, and the total of primary and specular and diffuse reflected atomic oxygen flux at each point on the structure. This table is written to standard output. Execution of SHADOWV2 concludes by calling subroutine CONNEC to generate a text file suitable for plotting by TECPLOT after processing by the TECPLOT PREPLOT module. This file contains the logarithms of the various fluxes at each point and a connectivity matrix which tells TECPLOT how to connect the points making up the structure.

3.1.2 Program Flow for MDDB Version 2.0

Figure 3.1.2-1 shows the MDDB block diagram. The names of major subroutines in the block diagram are given in parenthesis. Figure 3.1.2-2 is a subroutine tree for MDDB and shows all subroutines and functions and their calling hierarchy. The majority of MDDB execution involves user responses to prompts printed to screen by MDDB. Major computational routines to specify surfaces point by point from the geometry definition such as CONNECM, RAYG1M, RAYG2M, and RAYG3M are stripped down versions of the subroutines of similar name in SHADOWV2. Consequently, detailed description of the algorithms used in MDDB is unnecessary.

MDDB starts execution by asking the user whether he or she wishes to create an input file for SHADOW Version 1.X or SHADOWV2 or SOLSHAD and whether to create a new input file or to edit an existing one. If the user chooses to edit an existing input file, MDDB asks the user to specify the program to which the file to be edited applies and asks for the filename. The data from the file are read in. At this point the user has access to edit all of the surfaces in the object. In addition, the user may perform any of the file building and editing operations available when a new input file is being created. These operations are described below.

If a new input file is chosen, the user is prompted to enter the geometry and surface property definition for the first surface. When the data have been entered, the user is given the opportunity to display the surface using TECPLOT. When display mode is selected, the geometry specifications are written to a scratch file on unit 11. This file is read by subroutine RAYG1M which does preliminary setup and interpretation on the geometry inputs. Subroutine CONNECM calls subroutine RAYG2M to locate the Cartesian coordinates of each point on the surface of the structure. These points are written to a binary file directly readable by TECPLOT and to an ASCII file which may be used by PREPLOT. Outward normal arrows from the active side of surfaces are also generated and written to these files. Last, the finite element connectivity matrix specifying how points on surfaces are to be connected are generated and written to the files. The TECPLOT display shows all surfaces comprising the structure with direction arrows pointed outward from the active side of each surface.

The user may choose to rotate or translate the surface and look at it again with TECPLOT. If the user does not like the operation just performed, he may undo it. Surface rotations take place about rotation axes parallel to the Cartesian x, y, and z axes. The user specifies the position of these axes. This gives greater freedom to move a surface than a rotation about one of the coordinate axes.

When the first surface specification is complete or if the user is editing an existing input file, a menu of actions is presented. Actions include adding a new surface after the last entered surface or inserting a new one between existing surfaces, deleting a surface, reviewing surface (listing them with an optional TECPLOT display of the structure), modifying an existing surface, or copying an existing surface. The user repeats these actions until he or she is satisfied with the geometry and surface properties of the structure.

MDDB Block Diagram

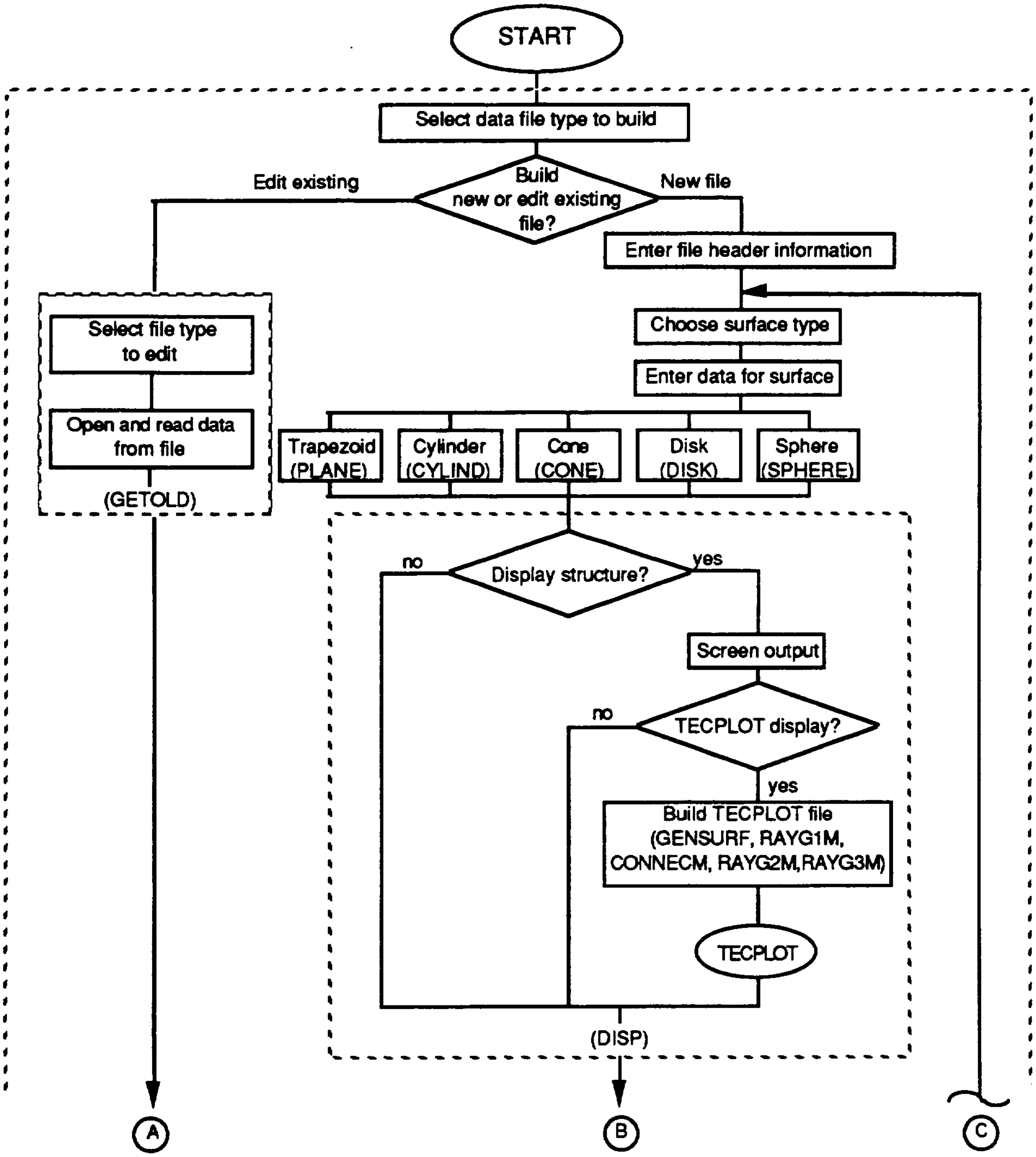

Figure 3.1.2-1. MDDB Block Diagram (Sheet 1 of 3).

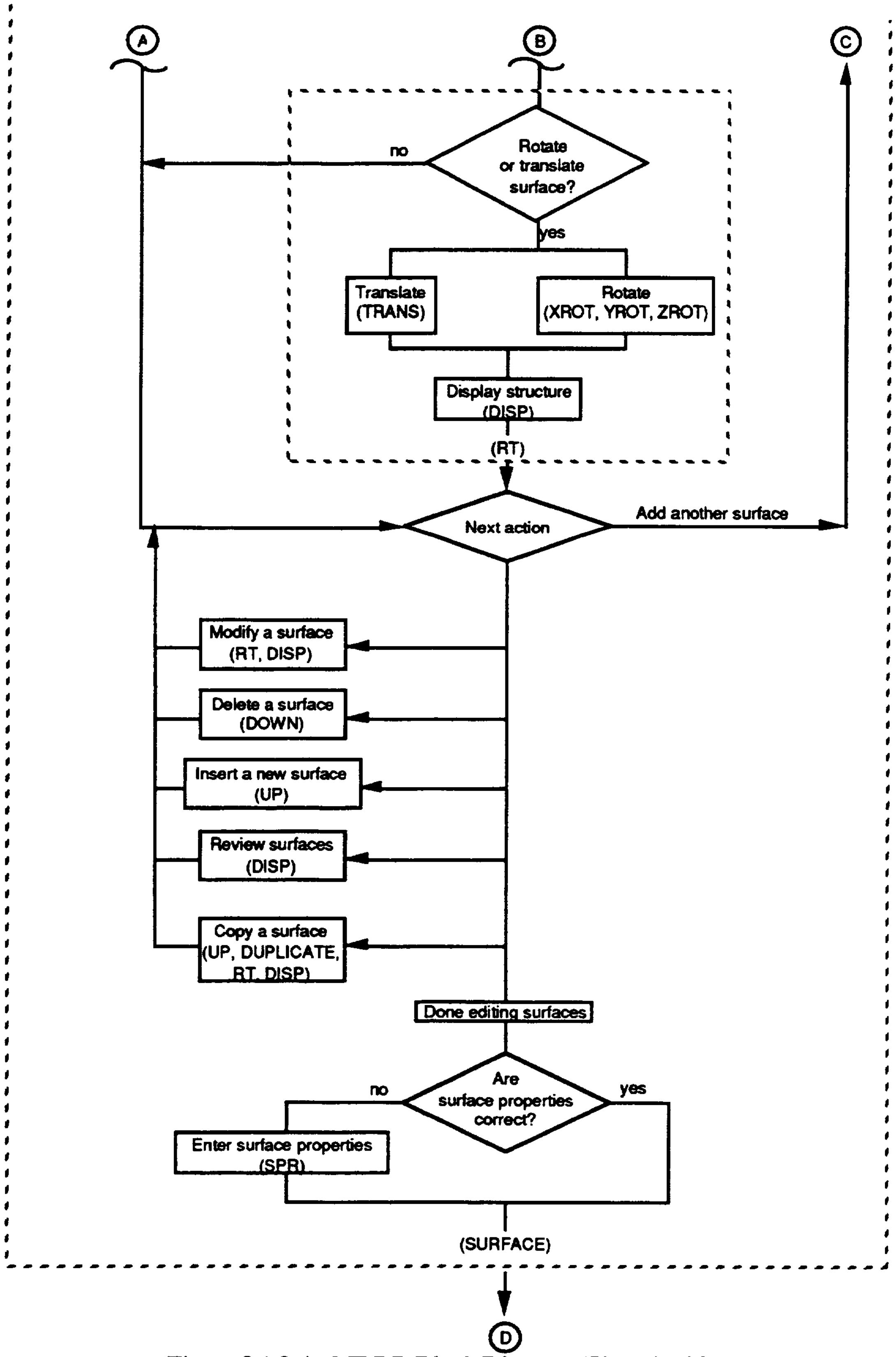

Figure 3.1.2-1. MDDB Block Diagram (Sheet 2 of 3).

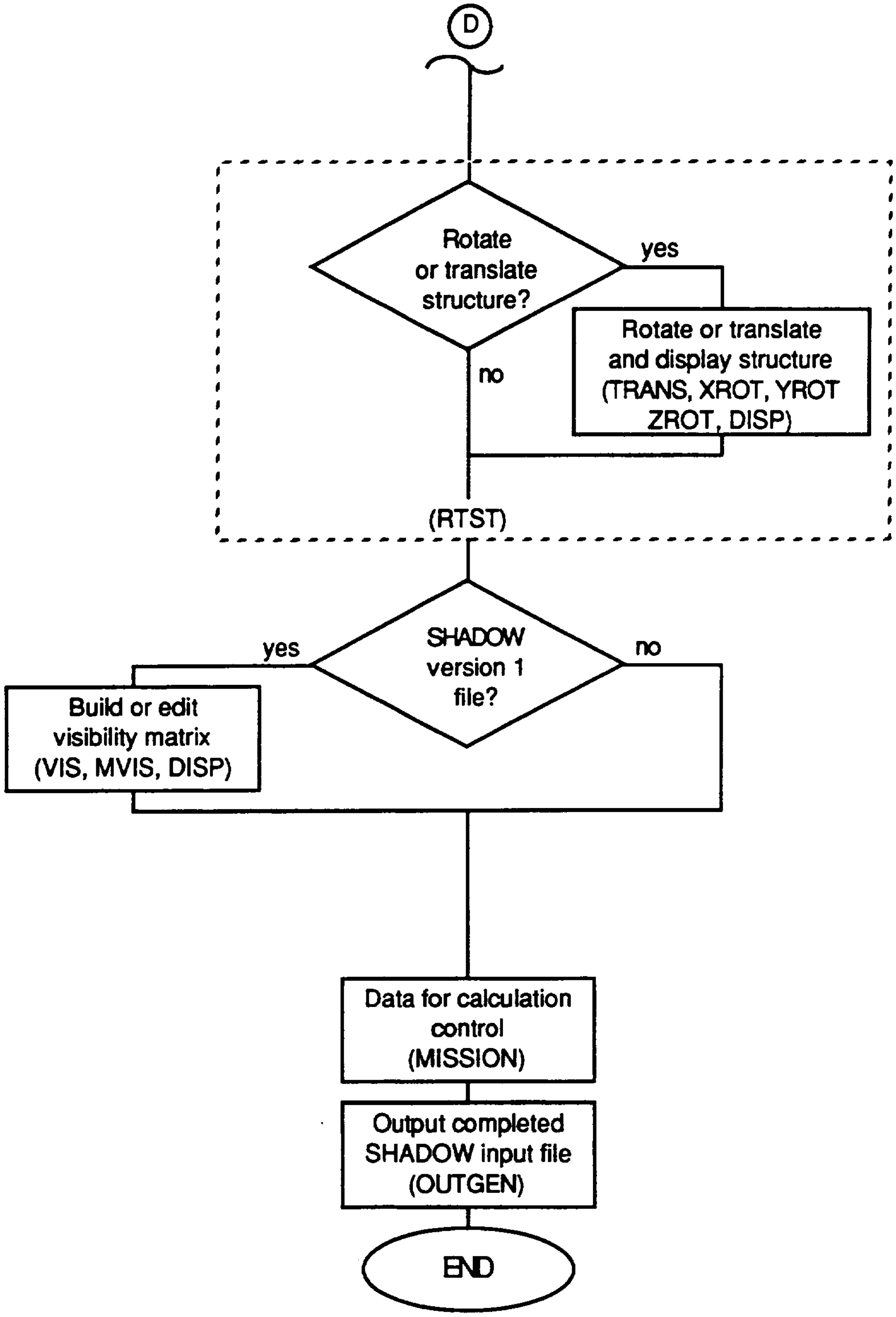

Figure 3.1.2-1. MDDB Block Diagram (Sheet 3 of 3).

MDDB Version 2.0 Subroutine Tree

```
MDDB ┬ SURFACE ┬ LES
     │         ├ GETOLD ┬ RDLNC ── NEXTNB
     │         │        └ SHUFL
     │         ├ RDLNC ── NEXTNB
     │         ├ RDLNI ┬ LES
     │         │       ├ NEXTNB
     │         │       └ LASTNB ─ LES
     │         ├ PLANE ┬ RDLNC ── NEXTNB
     │         │       ├ RDLNR ┬ LES
     │         │       │       ├ NESTNB
     │         │       │       └ LASTNB ── LES
     │         │       ├ SPR ┬ RDLNC ── NEXTNB
     │         │       │     └ RDLNR . . .
     │         │       ├ SHUFL
     │         │       ├ DISP ┬ LES
     │         │       │      └ GENSURF ┬ RAYG1M ─ RG1ERR
     │         │       │                ├ LES
     │         │       │                └ CONNECM ┬ LES
     │         │       │                          ├ RAYG2M
     │         │       │                          ├ RAYG3M
     │         │       │                          └ SWITCH
     │         │       └ RT ┬ TRANS ── SHUFL
     │         │            ├ DISP . . .
     │         │            ├ SHUFL
     │         │            ├ XROT ┬ COSD
     │         │            │      └ SIND
     │         │            ├ YROT ┬ COSD
     │         │            │      └ SIND
     │         │            └ ZROT ┬ COSD
     │         │                   └ SIND
     │         ├ CYLIND ┬ RDLNC ── NEXTNB
     │         │        ├ RDLNR . . .
     │         │        ├ VECMAG
     │         │        ├ CROSS
     │         │        ├ SPR . . .
     │         │        ├ SHUFL
     │         │        ├ DISP . . .
     │         │        └ RT . . .
     │         ├ CONE ┬ RDLNC ── NEXTNB
     │         │      ├ RDLNR . . .
     │         │      ├ VECMAG
     │         │      ├ CROSS
     │         │      ├ SPR . . .
     │         │      ├ SHUFL
     │         │      ├ DISP . . .
     │         │      └ RT . . .
     ▼         ▼
    (A)       (B)
```

Figure 3.1.2-2. MDDB Subroutine Tree (Sheet 1 of 2).

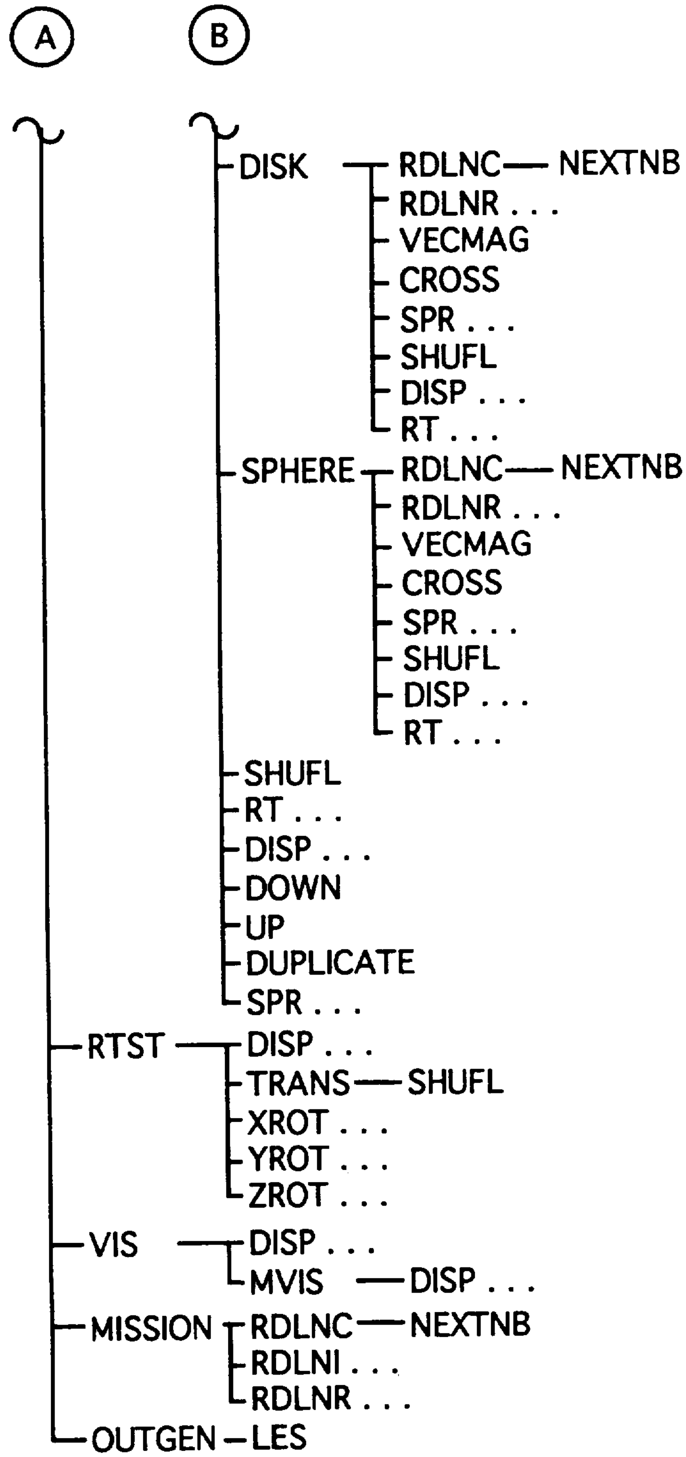

Figure 3.1.2-2. MDDB Subroutine Tree (Sheet 2 of 2).

After the user has finished building the geometry for the structure, MDDB checks to see if surface properties are correct for the type of input file being built. For example, if the user is building a SHADOWV2 input file by editing an existing SOLSHAD input file, the surface properties must be changed even though the object geometry has not been changed.

After the user has finished building the geometry for the structure, the entire structure may be rotated or translated in the same manner as described for individual surfaces.

For SHADOW Version 1.X input files only, MDDB prompts the user to enter or edit the visibility matrix, which specifies which surfaces can see themselves or other surfaces. The user has similar options to those available during geometry building: he or she may display the structure, review the visibility matrix, modify it, or build it from scratch.

Last, the user enters new parameters or modifies existing parameters which control the atomic oxygen flux calculations for SHADOW version 1.X and SHADOWV2 or the CESH calculations for SOLSHAD. MDDB finishes execution by writing the completed input file to disk.

3.1.3 Program Flow for AVESHAD

AVESHAD takes data from a mission file and performs the following operations: inputs start and end dates; calculates the average density, velocity, and flux; and generates a new SHADOW input file with the new data. A block diagram is shown in Figure 3.1.3-1. The main program begins by calling **getDates** to get the start and end date. Then it calls **calcDen** which calculates the average fluxes and relative velocity. In order to do this, it calls **calcFluxes**. This routine integrates the velocity over the time range using trapezoidal approximation, as well as finding the fluence for ram and 90 deg at the start and end of the event. The average velocity is found from dividing the integral by the total time, and the average flux is determined by subtracting the end fluence by the start fluence, and dividing by the total time. **calcDen** then calculates the average atomic oxygen density from these values. The main program calls **calcTemp** next to calculate the average temperature. Finally, it calls **createInput**, which reads an old input file line by line, and generates a new input file where the calculated values of velocity, density, and temperature are substituted for the original values.

3.1.4 TECPLOT Macros

There are three macros to generate plots in TECPLOT. This section briefly describes what these macros do.

File: **p.mcr**
1. Convert the ASCII file MDDB.PRE to MDDB.PLT (Workstation macros only).
2. Load the file MDDB.PLT.
3. Turn off graphics.
4. Create a mesh plot in 3D. (TECPLOT version 5 macros: assign the Z axis to the last variable.)
5. Assign the X, Y, and Z axis to the last three variables.
6. Choose to make a hidden line plot.
7. Export the mesh so that it will show up in the contour plot.
8. Create a contour plot using the surface number (second variable) as the contour variable.
9. Set zones as filled.
10. Get rid of axes. (Not needed in TECPLOT version 5 macros.)
11. Rotate it 30 deg in the X, Y, and Z directions to give it better perspective.
12. Make sure the rotated plot fits in the screen.
13. Activate the graphics and generate the plot.

AVESHAD BLOCK DIAGRAM

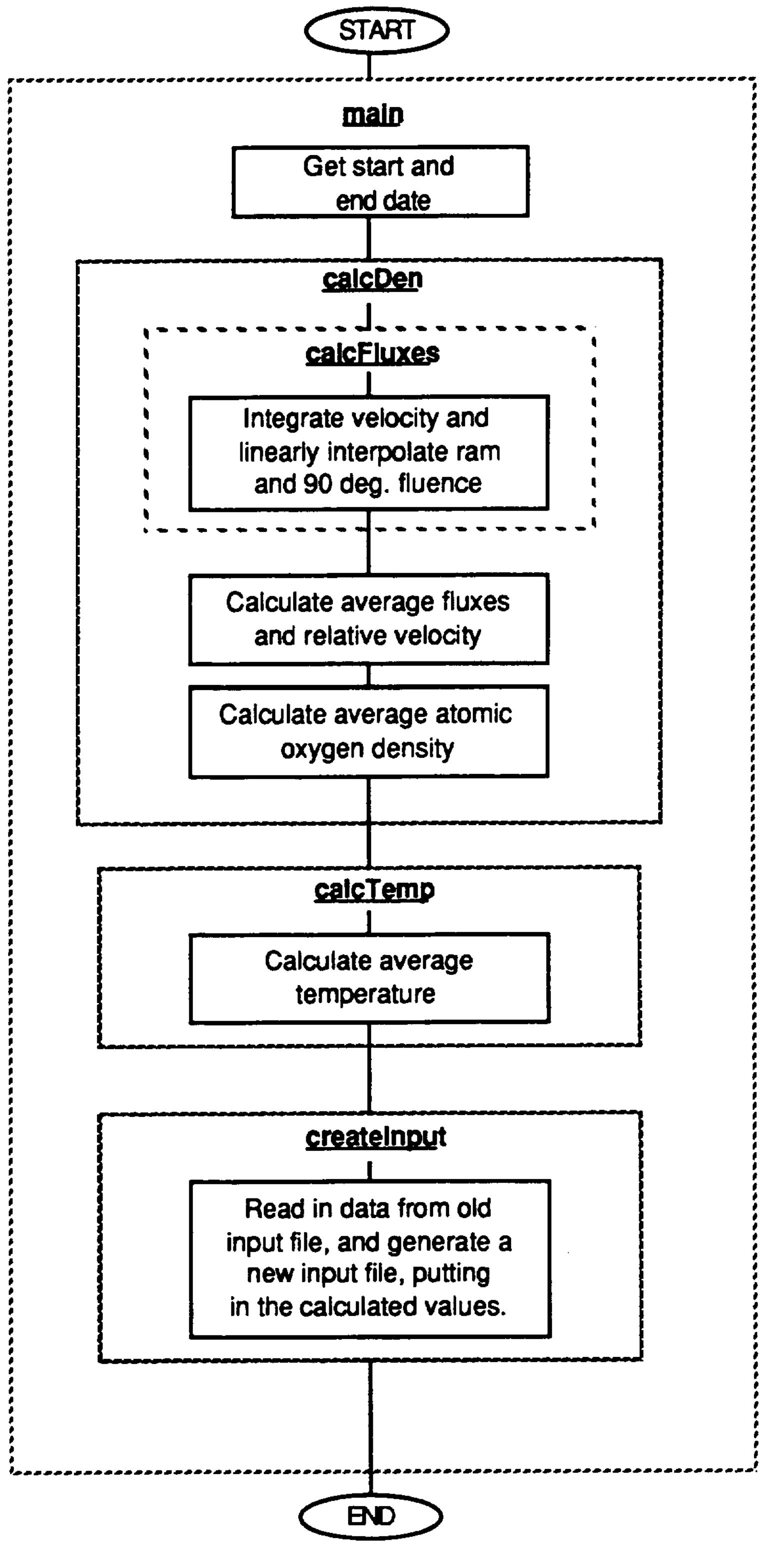

Figure 3.1.3-1. AVESHAD Block Diagram.

File: **table.mcr**
1. Choose new contour levels: maximum, minimum and delta.
2. Set minimum level to 1.
3. Put the message "Enter total number of surfaces" at the bottom of the screen.
4. Get user input for maximum level.
5. Set delta level to 1.
6. Place the table.
7. Get user input on where to place table, while displaying the message "Place the table."
8. Regenerate plot.

File: **shadow.mcr**
1. Turn off graphics.
2. Create a mesh plot in 3D. (TECPLOT version 5 macros: assign the Z axis to the last variable.)
3. Assign the X, Y, and Z axis to the last three variables.
4. Choose to make a hidden line plot.
5. Export the mesh so that it will show up in the contour plot.
6. Create a contour plot using the total flux (fourth variable from the end) as the contour variable.
7. Set zones as filled.
8. Get rid of axes. (Not needed in TECPLOT version 5 macros.)
9. Make sure the rotated plot fits in the screen.
10. Activate the graphics and generate the plot.

3.2 ALGORITHMS IN THE MICROENVIRONMENT AO EXPOSURE PROGRAM

3.2.1 SHADOWV2 Algorithms

This section describes the algorithms used in SHADOWV2. Each algorithm is described independently of the others. Refer to section 3.1.1 for information on where the algorithms are used in SHADOWV2.

Four-Point Lagrange Interpolation. Consider a series of points x_n and a series of values y_n corresponding to the x_n. Suppose one wishes to interpolate the value of y corresponding to point x, $x_1 \leq x \leq x_2$. A four-point Lagrange interpolation is one way to perform the desired interpolation. The formula for this interpolation is

$$y(x) \approx \frac{(x-x_1)(x-x_2)(x-x_3)}{(x_0-x_1)(x_0-x_2)(x_0-x_3)}y_0 + \frac{(x-x_0)(x-x_2)(x-x_3)}{(x_1-x_0)(x_1-x_2)(x_1-x_3)}y_1 +$$

$$\frac{(x-x_0)(x-x_1)(x-x_3)}{(x_2-x_0)(x_2-x_1)(x_2-x_3)}y_2 + \frac{(x-x_0)(x-x_1)(x-x_2)}{(x_3-x_0)(x_3-x_1)(x_3-x_2)}y_3 \qquad (3.2.1.1)$$

This formula works whether or not the x_n are equally spaced. However, if the x_n are equally spaced with spacing Δx, the formula reduces to

$$y(x) \approx \frac{(x-x_1)(x-x_2)(x-x_3)}{-6(\Delta x)^3} y_0 + \frac{(x-x_0)(x-x_2)(x-x_3)}{2(\Delta x)^3} y_1 +$$

$$\frac{(x-x_0)(x-x_1)(x-x_3)}{-2(\Delta x)^3} y_2 + \frac{(x-x_0)(x-x_1)(x-x_2)}{6(\Delta x)^3} y_3 . \tag{3.2.1.2}$$

Simpson's Rule for Integration. Suppose one wishes to numerically integrate the function y(x) over the range from x = a to x = b. Simpson's rule provides one method for performing this integration. Divide the interval $a \leq x \leq b$ into an even number n of intervals of spacing h such that nh = (a-b). Then

$$\int_a^b y(x)dx \approx \frac{h}{3}(y_0 + 4\,y_1 + 2y_2 + 4\,y_3 + \ldots + 4\,\,y_{n-3} + 2y_{n-2} + 4\,y_{n-1} + y_n) \tag{3.2.1.3}$$

where $y_i = y(x_i)$, $0 \leq i \leq n$.

Directional Flux. The directional flux (that is, the flux per unit solid angle) of atomic oxygen from a given direction depends only on the angle between ram (the satellite heading) and the direction of interest. The calculation of the directional flux seen by a moving satellite is performed in two steps. First, the number of oxygen atoms in a given velocity (speed and direction) class is calculated in a coordinate system fixed in space. Then, this velocity class is transformed into the moving reference frame of the satellite and this is used to calculate the directional flux in the satellite reference frame. When the directional fluxes from all velocity classes in the satellite reference frame have been accumulated, one has the directional flux distribution. This section gives details of the calculations.

Consider the atomic oxygen molecules in a coordinate system at rest with respect to the mean molecular flow velocity and with a polar axis in the ram reversed direction as shown in figure 3.2.1-1. In this coordinate system the molecules will have a Maxwell velocity distribution. Divide the molecules into velocity classes centered at the polar angle β and molecular speed c and with dimensions $\Delta\beta$ and Δc, respectively. Each class represents the number of molecules per unit solid angle per unit velocity:

$$\frac{\partial^2 N}{\partial \omega_\beta \partial c} = NGH \tag{3.2.1.4}$$

where

N = the number of molecules/cm^3;

$$G = \left(\frac{M}{2\pi RT}\right)^{\frac{3}{2}} \left[\exp\left(\frac{-Mc^2}{2RT}\right)\right] 4\,\pi c^2, \tag{3.2.1.5}$$

the Maxwell speed distribution;

$H = 1/4\,\pi$, the angular distribution of the velocities;

and M is the molecular molar mass (16 g/mole for atomic oxygen), R is the ideal gas constant (8.31441E7 erg/(g mole K)), T is the temperature (K), and c is the molecular speed (cm/s).

$$\Delta\omega_\beta = 2\,\pi\,\sin(\beta)\,\Delta\beta \tag{3.2.1.6}$$

is the increment of solid angle as a function of polar angle β. The factor of $2\,\pi$ is there because all azimuthal directions are equivalent.

Then, the number of molecules in a velocity class is

$$\Delta N = \frac{\partial^2 N}{\partial\omega_\beta \partial c}\,\Delta\omega_\beta\,\Delta c. \tag{3.2.1.7}$$

In SHADOWV2, β ranges from 0 to 180 degrees and this range is divided into 720 equal intervals. The molecular speed c is stepped from 0 in increments of 0.01 of the average molecular speed

$$\bar{c} = \left(\frac{8\,RT}{\pi\,M}\right)^{\frac{1}{2}} \tag{3.2.1.8}$$

until convergence is reached.

The second step of the calculation of directional flux is to transform the velocity class ΔN from the rest coordinate system to the satellite coordinate system. As shown in figure 3.2.1-1, the relative velocity u between the satellite and the molecular velocity class is the ram (satellite) reversed velocity v added to the molecular velocity c and angle α between u and v. From the law of cosines,

$$u^2 = v^2 + c^2 - 2\,v\,c\cos(\beta) \tag{3.2.1.9}$$

and

$$\cos(\alpha) = \frac{u^2 + v^2 - c^2}{2\,u\,v} \tag{3.2.1.10}$$

The flux due to velocity class c as seen by the satellite is

$$\Delta F = (\,\Delta N)\,u/\Delta\omega_\alpha \tag{3.2.1.11}$$

where

$$\Delta\omega_\alpha = 2\,\pi\sin(\alpha)\,\Delta\alpha. \tag{3.2.1.12}$$

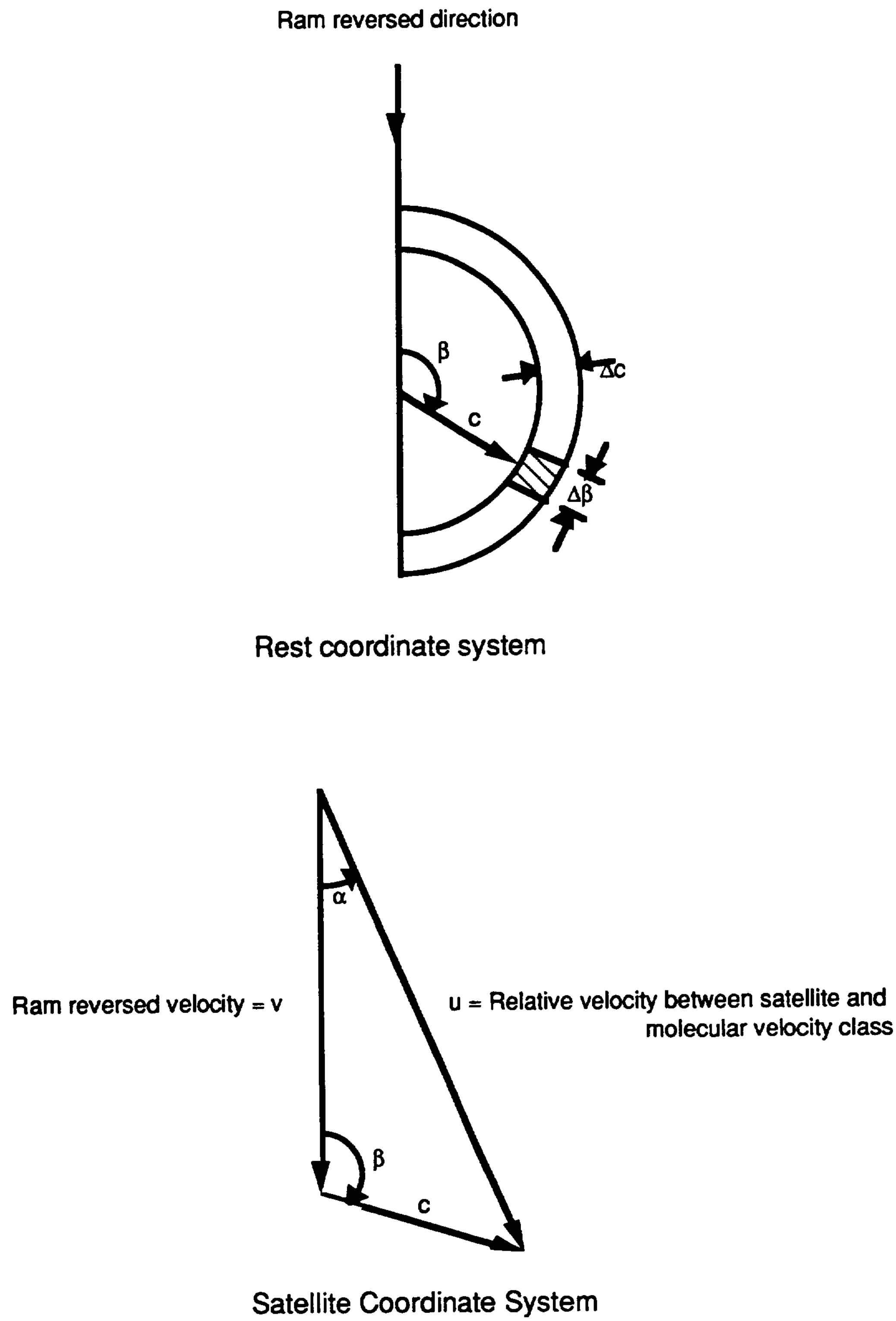

Figure 3.2.1-1. Directional Flux Distribution.

The range of α from 0 to 180 degrees is divided into equal angular increments $\Delta\alpha$ and ΔF is accumulated in the angular increment bin which includes angle α. In SHADOWV2 $\Delta\alpha$ is 1 degree.

This process is repeated for all angles β for a given molecular speed class c before c is incremented to the next speed class. The speed class is increased either until the fractional change in the flux at 180 degrees is less than 10^{-6} or until c exceeds 2.5 times the maximum of the satellite or average molecular speed.

In the algorithm used in subroutine GENDFDW, N in equation (3.2.1.4) has been set to 1.0, so that what is generated is really a directional flux distribution. This distribution is converted to a directional flux by multiplying it by the actual molecular density.

It will be noted that the same combination of factors in several equations, angular increments, and solid angles recur. These values are precalculated and stored whenever possible to speed up execution of subroutine GENDFDW. As currently written, approximately 700,000 velocity classes must be considered to generate the directional flux distribution for a typical temperature of 1020 K and satellite speed of 7.4E5 cm/s.

Directional Flux on a Surface From a Ray to Space. As described in section 3.1.1, the flux on a point on a surface is calculated by sending rays out through the grid of directions defined on the half sphere centered on the outward surface normal at the point and integrating the directional flux on the surface from each direction. The details for calculating the directional flux on a point on the surface are given here. Note that in the following all vectors are defined to be unit vectors and all vectors are indicated by **bold** type.

Consider a point P on a surface with outward normal vector **N** and tangent vectors $\mathbf{T_x}$ and $\mathbf{T_y}$ as shown in figure 3.2.1-2. $\mathbf{T_x}$, $\mathbf{T_y}$, and **N** and the ram direction vector **Z** are defined in the Cartesian coordinate system used to define the surface, but generally are not aligned with the axes of this system. $\mathbf{T_x}$, $\mathbf{T_y}$, and **N** form a right handed coordinate system such that $\mathbf{T_x} \times \mathbf{T_y} = \mathbf{N}$. In this surface normal coordinate system the direction of a ray to space **A** is defined by polar angle θ and azimuth angle ϕ. The directional flux on the surface from direction **A** is a function of β, the angle between the ram direction **Z** and **A**. The problem is to determine β in terms of known quantities.

In the ($\mathbf{T_x}$, $\mathbf{T_y}$, **N**) coordinate system,

$$\mathbf{A} = \sin\theta\cos\phi\,\mathbf{T_x} + \sin\theta\sin\phi\,\mathbf{T_y} + \cos\theta\,\mathbf{N} \qquad (3.2.1.13)$$

Note that the projection of **A** on **Z** is

$$\begin{aligned}\cos\beta &= \mathbf{A}\cdot\mathbf{Z} \\ &= \sin\theta\cos\phi\,(\mathbf{T_x}\cdot\mathbf{Z}) + \sin\theta\sin\phi\,(\mathbf{T_y}\cdot\mathbf{Z}) + \cos\theta\,(\mathbf{N}\cdot\mathbf{Z})\end{aligned} \qquad (3.2.1.14)$$

Because the ray direction **A** is varied over the (θ, ϕ) grid when calculating the direct flux at P, the appropriate unit of solid angle is

$$d\Omega = \sin\theta\, d\theta\, d\phi \qquad (3.2.1.15)$$

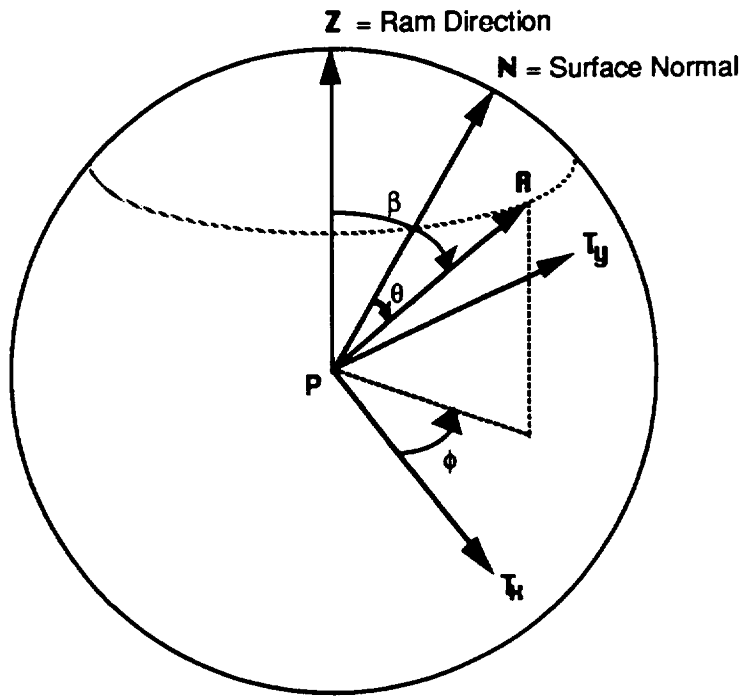

Figure 3.2.1-2. Projection of Ray to Space on Ram Direction.

and the flux at P from direction A is

$$F_A = \frac{dF(\beta)}{d\Omega} \cos\theta \, d\Omega \qquad (3.2.1.16)$$

Where $\frac{dF(\beta)}{d\Omega}$ is the directional flux at angle β to ram. The factor cos θ in equation 3.2.1.16 accounts for the projected area of the directional flux on the surface at P.

Direct Flux on an Unshielded Surface. Molecules in a gas in thermal equilibrium have a Maxwellian speed distribution characteristic of their temperature. At 1000°K, the average molecular speed of atomic oxygen is 1.15 km/sec. The average speed of a spacecraft relative to the atmosphere at 400-km altitude in an easterly orbit is 7.24 km/sec. Because of thermal molecular motion, atomic oxygen flux on a surface at high incidence angles is not accurately given by the product of number density, spacecraft velocity, and projected surface area. An equation to account for the effect of thermal molecular velocity as well as vehicle velocity is derived in the following paragraphs.

The velocity of a molecule with respect to the spacecraft is the vector sum of its thermal velocity and the velocity of the spacecraft reversed. This relationship is shown in figure 3.2.1-3.

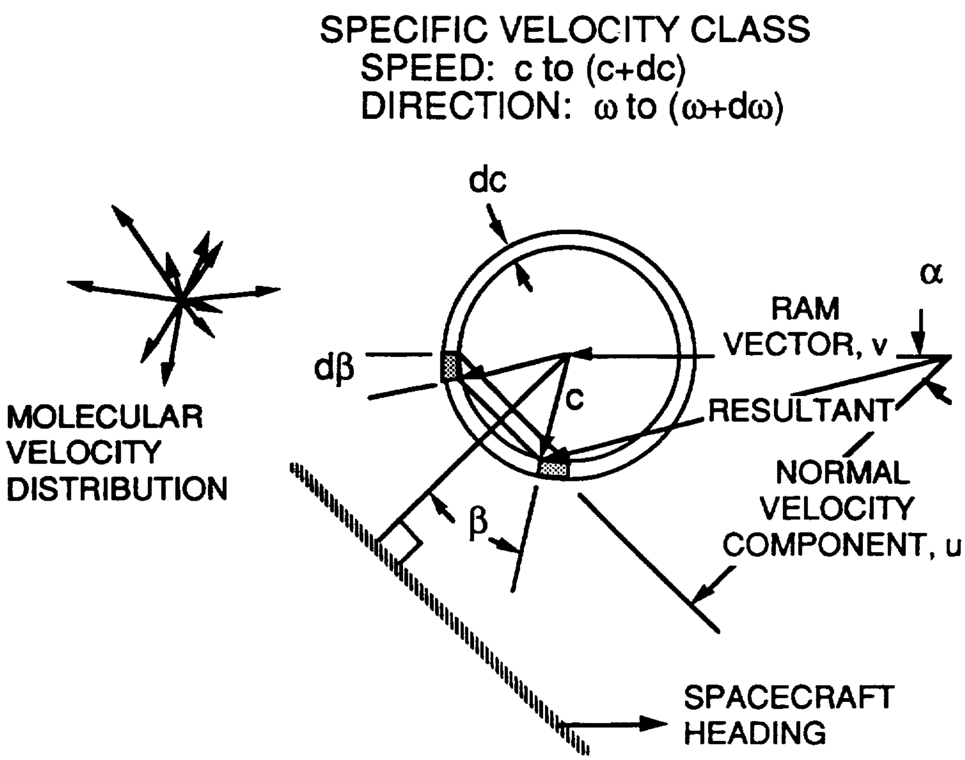

Figure 3.2.1-3. Addition of Spacecraft and Thermal Molecular Velocity Vectors.

The thermal velocity of a molecule is described by two distribution functions. G(c), the Maxwell speed distribution function (eq. 3.2.1-5) represents the fraction of N total molecules with speed in the range c to (c+ dc). The value of the speed distribution function varies with temperature.

H, the solid angle distribution function, represents the fraction of molecules with velocity vectors directed in the range of solid angles ω to $(\omega + d\omega)$. Since all directions of the velocity vector are equally probable, the solid angle distribution function is a constant, $H = 1/4\pi$.

The population of atomic oxygen molecules in the vicinity of the spacecraft is considered to be divided into infinitesimal velocity classes. For a given velocity class, molecular velocity is added to the ram vector to obtain the velocity of molecules in the class relative to the spacecraft. The component of relative velocity perpendicular to the spacecraft surface for the specified molecular velocity class is

$$u = v \cos \alpha + c \cos \beta \qquad (3.2.1.17)$$

where α is the angle between the spacecraft surface normal and the ram vector and v is the ram vector magnitude.

Using the relative velocity equation and the two distribution functions, an equation is derived for flux at the surface caused by molecules contained in the velocity class. This equation is modified by expressing solid angle in terms of plane angle measured from the surface normal.

$$\frac{\partial^2 F}{\partial c \partial \omega} = HGNu \tag{3.2.1.18}$$

$$\frac{\partial \omega}{\partial \beta} = 2\pi \sin\beta \tag{3.2.1.19}$$

$$\frac{\partial^2 F}{\partial c \partial \beta} = \frac{1}{4\pi} GNu(2\pi \sin\beta) \tag{3.2.1.20}$$

The derivation yields a differential equation for molecular flux in terms of two independent variables and four constants. The independent variables are thermal molecular speed and the direction of the molecular velocity vector relative to the surface. The constants are temperature, number density, spacecraft velocity, and the angle the surface makes with the ram direction of the vehicle.

The differential equation for flux (eq. 3.2.1.20) is integrated with respect to the independent variables, molecular speed and angle, to obtain an equation for flux in terms of temperature, number density, spacecraft velocity, and incidence angle. Values for the latter items are held constant during the integration process. To arrive at the equation for flux, limits for integration are devised for leading surfaces to include all molecules swept out by the advancing surface.

The gas molecules surrounding the spacecraft are separated into two speed populations. The first population includes those molecules that do not have sufficient velocity to "outrun" the spacecraft even if traveling directly away from the spacecraft surface. The second population includes those molecules that can "outrun" the advancing surface if traveling in a path directed at a sufficient angle away from the surface. Molecules that "outrun" the spacecraft are not included within the limits.

$$F = \int_0^{v\cos\alpha} \int_0^{\pi} \left(\frac{\partial^2 F}{\partial c \partial \beta}\right) \partial\beta \partial c + \int_{v\cos\alpha}^{\infty} \int_0^{\cos^{-1}[(-v\cos\alpha)/c]} \left(\frac{\partial^2 F}{\partial c \partial \beta}\right) \partial\beta \partial c \tag{3.2.1.21}$$

Integration limits for trailing surfaces (surfaces on the aft side of the spacecraft) can be devised to include molecules with velocities such that they can catch the spacecraft. However, the resulting integral is identical to that derived for leading surfaces. Hence, the integral shown leads to a valid equation for flux (atoms per unit area per unit time) for both leading and trailing surfaces as follows:

$$F = \frac{1}{4} N \langle c \rangle \left\{ \exp\left(-U^2\right) + U\sqrt{\pi}\left[1 + \mathrm{erf}(U)\right] \right\} \tag{3.2.1.22}$$

where

$$\langle c \rangle = \sqrt{\frac{8RT}{\pi M}} \tag{3.2.1.23}$$

and

$$U = \frac{2}{\sqrt{\pi}} \left(\frac{v}{<c>} \right) \cos\alpha; \qquad (3.2.1.24)$$

To simplify the equation 3.2.1.22, terms resulting from the integration process have been gathered into two expressions. The first expression, $<c>$, can be recognized as the equation for average molecular speed consistent with kinetic molecular theory. The second expression, U, is a dimensionless statement for the normal component of speed for the advancing surface relative to average molecular speed multiplied by constant factors that appear in the integral.

Equation 3.2.1.22 has been derived elsewhere in connection with research on heat transfer and drag in rarefied gases (ref. 8).

To illustrate agreement with kinetic theory, two specific limiting cases are considered: (1) zero spacecraft velocity and (2) zero average molecular speed (zero temperature).

If $v = 0$, then

$$F = 1/4\ N <c> \qquad (3.2.1.25)$$

If $<c> = 0$, then

$$F = Nv \cos \alpha \qquad (3.2.1.26)$$

Otherwise

$$F = 1/4\ N <c> f(U) \qquad (3.2.1.27)$$

In the case of zero spacecraft velocity, $v = 0$, the equation is identical to that for the collisions by perfect gas molecules with a stationary plane surface In the case of zero temperature, $c = 0$, the equation is identical to that for a stationary gas of known density swept out by a moving surface. In equation 3.2.1.27, the function f(U) equals the quantity shown in braces in equation 3.2.1.22.

Monte Carlo Scattering. When an atom of atomic oxygen strikes a surface, it may undergo one of four fates: specular reflection, diffuse reflection, recombination with another atomic oxygen to form and O_2 molecule, or surface reaction. The probability of these fates depends on the surface properties of the surface being struck. The surface property of a fate is defined as the probability of that fate occurring.

The flux from a particular direction striking a point is divided into NRAY equal rays of flux (details of how NRAY is determined are given later in this section). A Monte Carlo selection of the fate of a ray of flux is made by choosing a random number between 0 and 1. The four surface property probabilities are arranged in the cumulative order shown in figure 3.2.1-4 and the fate is assigned to the bin which contains the random number. For example, if the specular reflection is 0.40, diffuse reflection 0.25, recombination 0.20, and surface reaction 0.15 and the random number is 0.53, the flux bundle will be diffusely reflected from the surface.

If recombination or surface reaction is selected, the flux due to the ray is accumulated under the proper heading and no further consideration is given the ray.

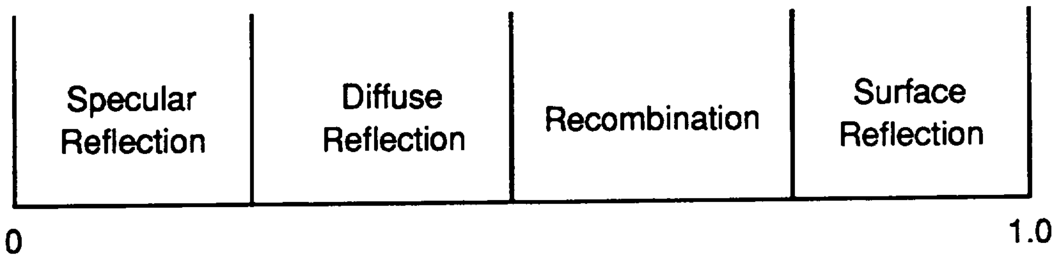

Figure 3.2.1-4. Cumulative Order of Surface Properties.

If specular reflection is selected, the ray is reflected from the surface as shown in figure 3.2.1-5; that is, the component of the ray normal to the surface is reversed. In the figure **R** is the ray to be reflected, **N** is the surface normal, and **S** is the specularly reflected ray. **R**, **N**, and **S** are all unit vectors. The normal component of **R** is **R**·**N**, so

$$\mathbf{S} = \mathbf{R} - 2(\mathbf{R} \cdot \mathbf{N})\,\mathbf{N} \qquad (3.2.1.28)$$

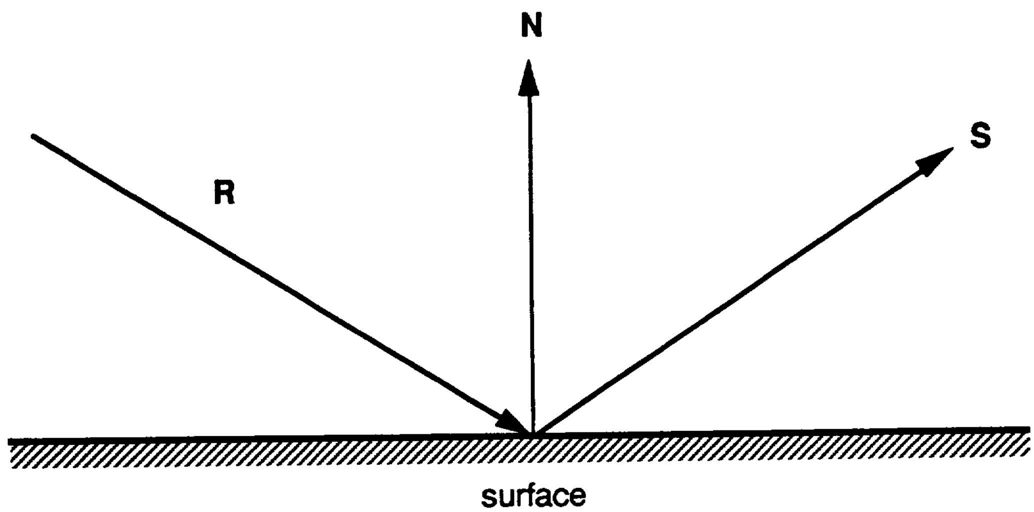

Figure 3.2.1-5. Specular Reflection.

Diffuse reflection is defined as having equal probability for any direction above the surface independent of the direction of the ray to be reflected. The reflection direction is randomly selected as follows (fig. 3.2.1-6). In the following all vectors are unit vectors. The surface normal vector at the point of ray intersection with the surface is **N** and $\mathbf{T_x}$ and $\mathbf{T_y}$ are tangent vectors. The normal component of the diffusely reflected direction vector **D** is chosen to be a random number r_n between 0 and 1 (the normal component of the reflected ray is always parallel to the surface normal vector). The components in the $\mathbf{T_x}$ and $\mathbf{T_y}$ directions are chosen as random r_x and r_y between -1 and +1. Last, r_n, r_x, and r_y are normalized so that $r_n^2 + r_x^2 + r_y^2 = 1$. Then,

$$\mathbf{D} = r_x\,\mathbf{T_x} + r_y\,\mathbf{T_y} + r_n\,\mathbf{N} \qquad (3.2.1.29)$$

The reflected ray, either **S** or **D**, is ray traced to determine if it hits another surface or not. If no surface is struck, the ray is not considered further. If a surface is struck, the ray is checked to see if the active side has been struck; if not, the ray is removed from further consideration. If the active side has been struck, the flux from the ray is distributed on the node struck on the surface. The procedure for this distribution is described later in this section.

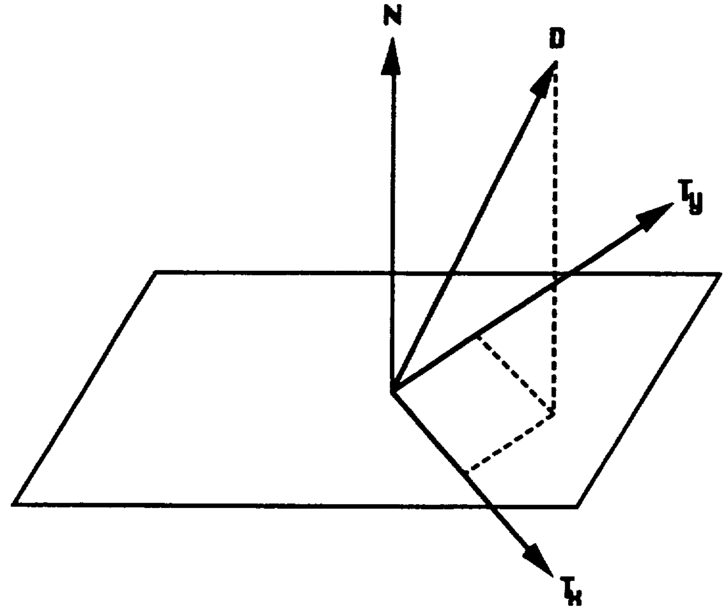

Figure 3.2.1-6. Diffuse Reflection.

The fate of the ray at this point is Monte Carlo selected and the ray is propagated as described above. This process continues until the ray is terminated by recombination, surface reaction, striking the inactive side of a surface, or propagation to space, or 100 reflections have taken place. This last condition prevents the possibility of an endless loop for rays trapped between highly reflecting surfaces.

The primary flux striking a node on a surface is calculated as the integral of the directional flux as a function of direction (eq. 3.2.1.16) over all unblocked directions in the half sphere above the active side of the node. This flux (atoms/cm^2) is independent of whether the area of the node is large or small.

A somewhat more sophisticated approach must be taken for calculating scattered flux than for calculating primary flux. Here, the areas of the nodes on the scattering surface and the receiving surface must be taken into account. Calculation of the areas of nodes is discussed in the Geometric Calculation and Ray Tracing Theory section. Consider figure 3.2.1-7. In the left half of the figure, a large area node scatters a uniform flux (atoms/area, represented by equally spaced arrows) toward a small area node. It is clear that only part of the atoms scattered from the large node is deposited on the small node; however, if the two nodes are parallel to each other, the small node receives the same average flux as the large node reflected. Now, consider the opposite case shown in the right half of the figure: a small area node scattering atoms to a large area node. Here (again, assuming that the two nodes are parallel to each other), all of the atoms scattered from the small node are deposited on the large node. However, the flux on the large node is smaller than that on the small node because even though all of the atoms scattered from the small node strike the large node, the flux on the large node (atoms/area of the large node) is smaller than that scattered from the small node. The scheme described below properly accounts for scattered fluxes from one node to another.

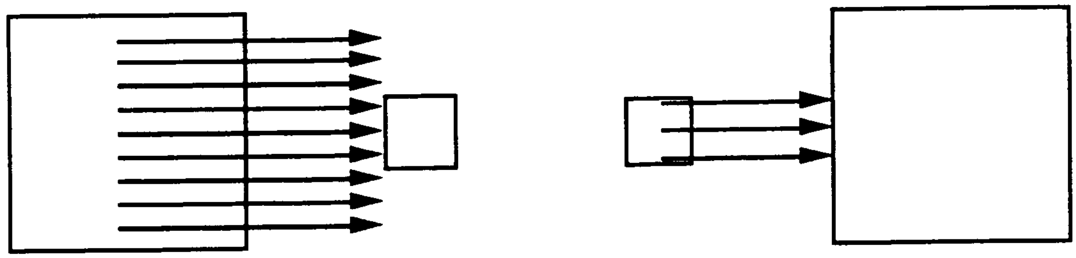

Figure 3.2.1-7. Scattering to Different Sized Areas.

The number of atoms of primary AO falling on a node is the primary flux times the projected area of the node, where the projected area is the actual area times the magnitude of the cosine of the angle between the ray direction and the node normal. This AO is divided into NRAY rays to be scattered from the area.

$$\mathrm{NRAY} = \mathrm{NINT}[(\mathrm{AREA(P)}\ \mathbf{RAY{\cdot}NRM})\ \mathrm{AMAXR} / \mathrm{ARMIN}] \qquad (3.2.1.30)$$

where AREA(P) is the area of the node receiving the primary AO; **RAY** is a unit vector in the ray direction; **NRM** is the node active side surface normal; AMAXR = MAXRAY times a scaling constant; MAXRAY / ARMIN is the number of rays MAXRAY per average nodal area ARMIN; and the term in parenthesis is the projected area of node scattering primary AO exposure. The scaling constant reduces the number of scattered rays when the directional flux is less than the maximum directional flux on the surface. The NINT function indicates that its argument should be rounded to the nearest integer. The number of atomic oxygen atoms in each of the NRAY rays is for a flux of 1 atom/unit area is

$$\mathrm{FFAC} = \mathrm{DLL}\ d\Omega \left(\frac{\mathrm{ARMIN}}{\mathrm{AREA(P)}}\right)\left(\frac{1}{\mathrm{AMAXR}}\right) \qquad (3.2.1.31)$$

where DLL is the directional flux of AO and dΩ is the solid angle subtended by the directional flux (eq.3.2.1.15). Then, the flux on the node receiving the scattered flux is

$$F_S = \mathrm{FFAC} / \mathrm{AREA(S)} \qquad (3.2.1.32)$$

where AREA(S) is the area of the node receiving the scattered flux.

To account for the distribution of scattered flux from the node receiving primary AO, each ray is scattered from a randomly selected point in the node.

Search for the Unblocked Ray With the Largest Directional Flux. The largest directional flux arriving at a point on a surface is used to set the number of rays to Monte Carlo scatter as described above. One way to determine this flux would be to ray trace the flux for every direction on the direction grid on the half sphere above the point on the active side of the surface and save the maximum value of directional flux. However, a more organized search can greatly reduce the amount of calculation needed. The search pattern used is based on the fact that the directional flux depends only on the angle between the ram direction and the direction from which the flux comes and the fact that the directional flux decreases monotonically as the angle increases from parallel to ram to antiparallel to ram.

The angle α between the ram direction unit vector **Z** and the outward normal unit vector **N** from point P on the active side of the surface (fig. 3.2.1-8) is determined from $\cos \alpha = \mathbf{Z} \cdot \mathbf{N}$. If $\cos \alpha > 0$, the active side of the surface may be exposed to flux from the ram direction. In this case, a ray in the ram direction is traced to see if it is unblocked; if so, the search is over.

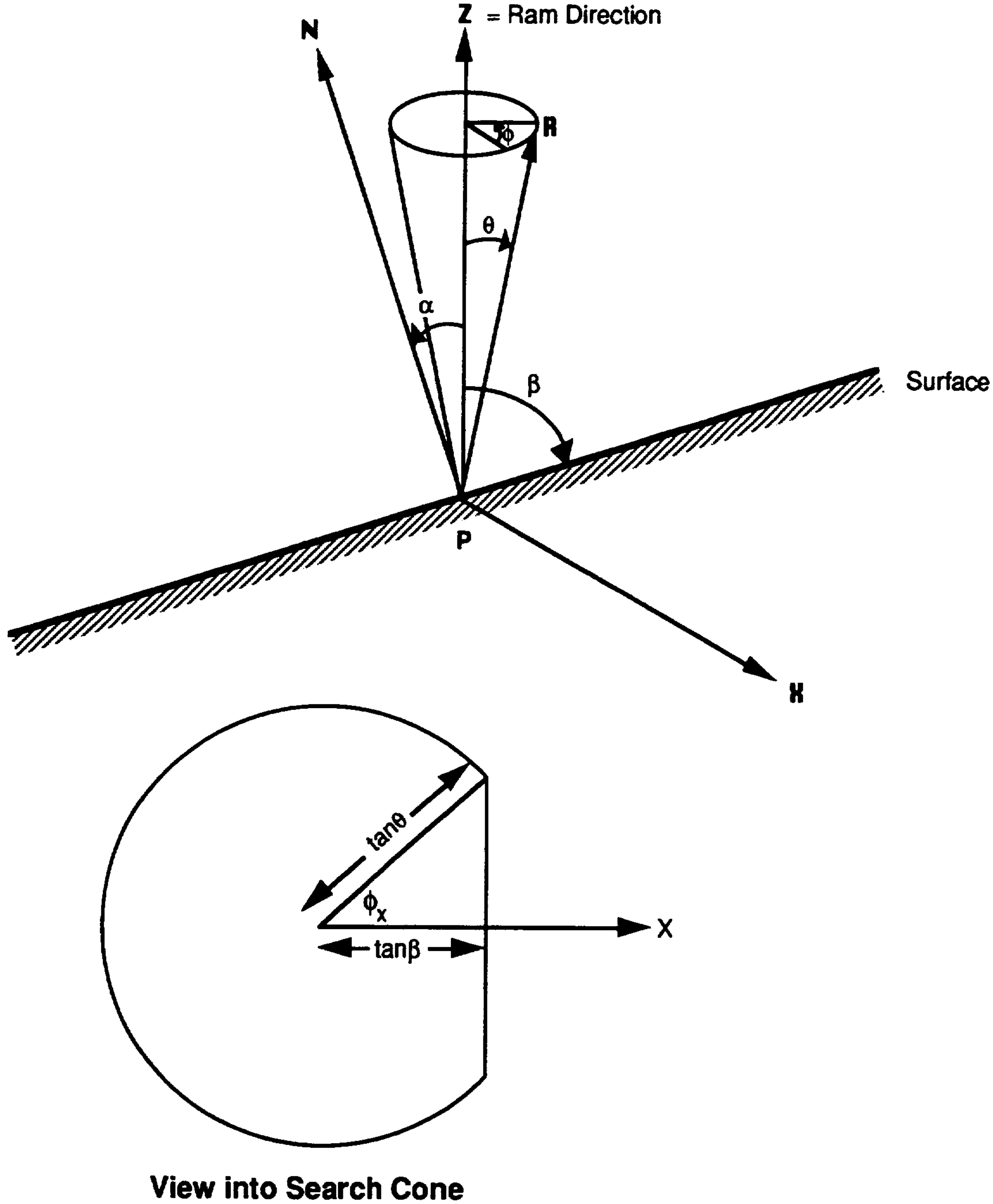

Figure 3.2.1-8. Search for Largest Directional Flux.

If no flux from the ram direction can strike P, the search for an unblocked ray takes place using rays directed from P to the rim of a cone with vertex at P and axis parallel **Z**. The cone is assumed to have unit height. The half angle θ of the cone is increased in uniform steps from zero and for each step, rays from P to equally spaced points around the rim are traced until an unblocked ray is found. If θ becomes ≥ 90 deg, the search is terminated and the direction of maximum flux is assigned to $\theta = 104$ deg because the directional flux has been found to vary by less than a factor of 10 for angles between 90 and 180 deg and conditions encountered in low Earth orbit.

Before proceeding with the details of the search, some definitions and observations are in order. The minimum angle between **Z** and a tangent plane to the surface at P is $\beta = |\,90 \text{ deg} - \alpha\,|$. Angle β is the maximum half angle the search cone can have before intersecting the tangent plane. The angle $90 \text{ deg} + \alpha = 180 \text{ deg} - \beta$ is the largest half angle that the search cone can have and still have some segment on the active side of the surface.

To handle the search cone, an axis set is defined as follows. The ram direction is in the direction of the Z axis. The X axis is perpendicular to Z, in the **Z**-**N** plane, and oriented as shown in figure 3.2.1-8 if $\alpha \leq 90$ deg and oriented in the opposite direction otherwise. The Y axis is oriented so that (X,Y,Z) form a right handed orthogonal set. In the event that **Z** and **N** coincide, the X and Y axes are in the direction of the two tangent vectors at P determined by the ray tracing routines.

The conditions limiting the range of β imply that limits must be placed on ϕ, the angle specifying position along the rim of the cone. ϕ is measured from the X axis toward the Y axis in the conventional spherical coordinates manner. These limits differ depending on whether $\alpha \leq 90$ deg or not and whether $\theta \leq \beta$ or not.

For the first case, consider $\alpha \leq 90$ deg. Then, if $\theta \leq \beta$, all values of ϕ from 0 to 360 deg are allowed. If $\theta > \beta$, then $\phi_x \leq \phi \leq 360 \text{ deg} - \phi_x$, where ϕ_x is the angle specifying the intersection of the cone with the tangent plane to the surface at P. Examination of the geometry of the intersection of the rim of the cone and the tangent plane reveals that the radius of the rim is tan θ (remember that the cone is defined to have unit height) and that the distance from the cone axis at the rim to the tangent plane is tan β. Then, ϕ_x may be determined from

$$\cos\phi_x = \frac{\tan\beta}{\tan\theta}. \qquad (3.2.1.33)$$

Because the search is terminated when $\theta \geq 90$ deg [that is, $\theta < 90$ deg always in equation (3.2.1.33)] and $\theta > \beta$, cos ϕ_x is always defined and $\phi_x < 90$ deg.

In the second case, $\alpha > 90$ deg and surface normal **N** and the ram direction **Z** point to opposite sides of the surface. For this case, the excluded part of the cone in the first case is now the included part and $360 \text{ deg} - \phi_x < \phi < \phi_x$.

Last, the ray direction **R** specified by θ and φ must be calculated in the Cartesian coordinates used to define the surface geometry. This is done in two steps: First, the projections of **R** on the (X, Y, Z) axes are calculated.

$$\mathbf{s}_x = \mathbf{x}\ \sin\theta\ \cos\phi \qquad (3.2.1.34)$$

$$\mathbf{s}_y = \mathbf{Y}\ \sin\theta\ \sin\phi \qquad (3.2.1.35)$$

$$\mathbf{s}_z = \mathbf{z}\ \cos\theta \qquad (3.2.1.36)$$

Then, because **X**, **Y**, **Z**, are defined in the Cartesian coordinates used to define the surface geometry,

$$\mathbf{R} = \mathbf{s}_x + \mathbf{s}_y + \mathbf{s}_z. \qquad (3.2.1.37)$$

Geometric Calculation and Ray Tracing Theory. The surface geometry description and ray tracing algorithms used in SHADOWV2 were developed by Dr. R. C. Corlett some years ago. The four geometry and ray tracing subroutines, RAYG1, RAYG2, RAYG3, and RAYG4, used are little modified except for style from those originally developed by Corlett. The algorithm description given below follows closely the description originally given by Corlett (ref. 9). Briefly, the four subroutines perform the following functions. RAYG1 reads the parametric description of the surfaces making the object and converts this description to the form used internally. RAYG2 returns the Cartesian coordinates of a point specified in internal coordinates. RAYG3 returns the normal to a surface at a given point as well as two orthogonal vectors tangent to the surface at the point. RAYG4 traces a ray in a given direction from a point and determines the closest surface which it intersects.

Surface geometry definition. Figures 3.2.1-9 through 3.2.1-13 describe the geometry of the five primary surfaces: the trapezoid, cylinder, cone, disk, and sphere, respectively, or portions of them. Each surface has an unambiguously defined positive (+) side and negative (-) side and a curvilinear coordinate system (ξ, η). The (ξ, η) coordinate system is normalized such that the primary surface occupies the region $[0 \le \xi \le 1, 0 \le \eta \le 1]$ exactly.

Each primary surface is divided into nodal surfaces. Each nodal surface is bounded by constant ξ and η boundaries. The positive and negative sides of the nodal surfaces match those of their primary surfaces. Figure 3.2.1-14 illustrates the layout of the nodal surfaces for NC = two nodes in the ξ direction and NN = three nodes in the η direction. The primary surfaces are defined in physically convenient parameters as described below.

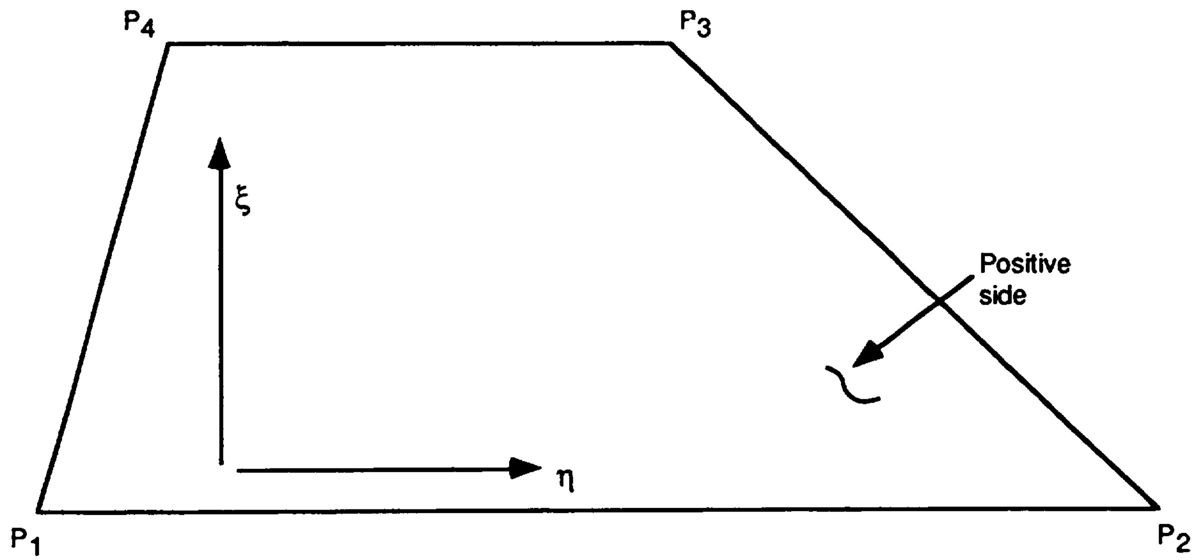

Figure 3.2.1-9. Trapezoid Geometry Definition.

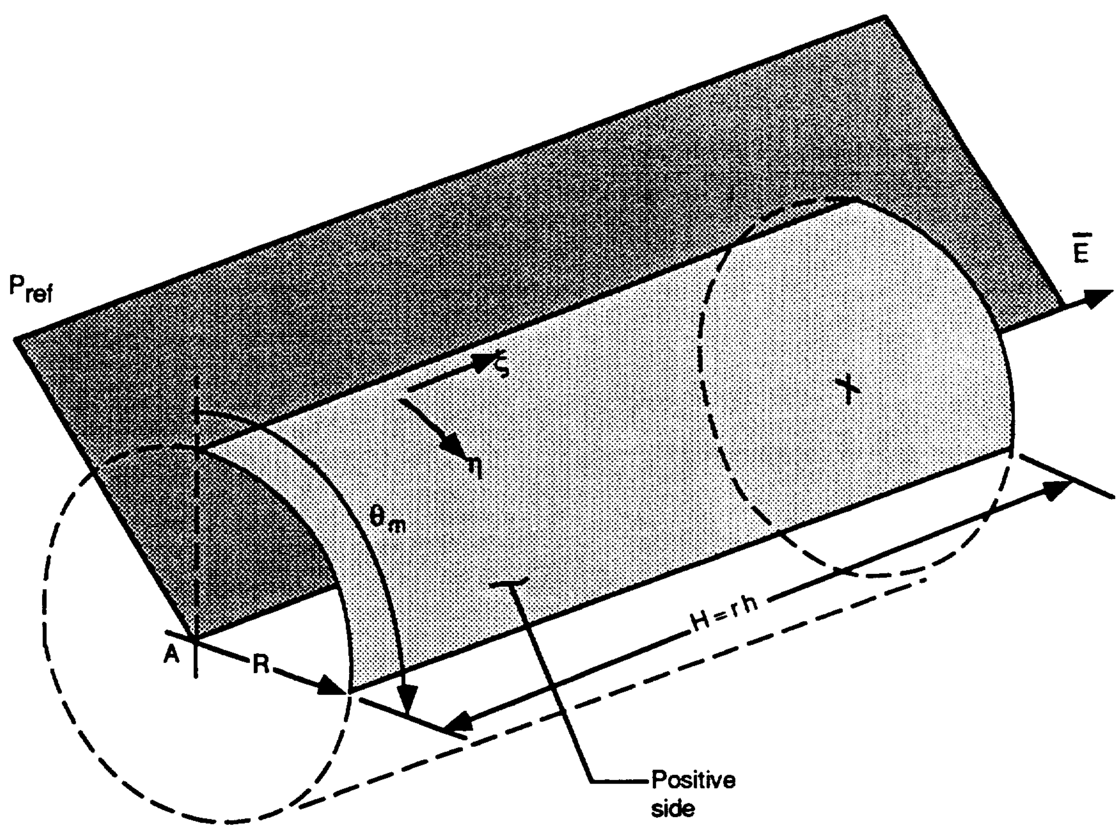

Figure 3.2.1-10. Cylinder Geometry Definition.

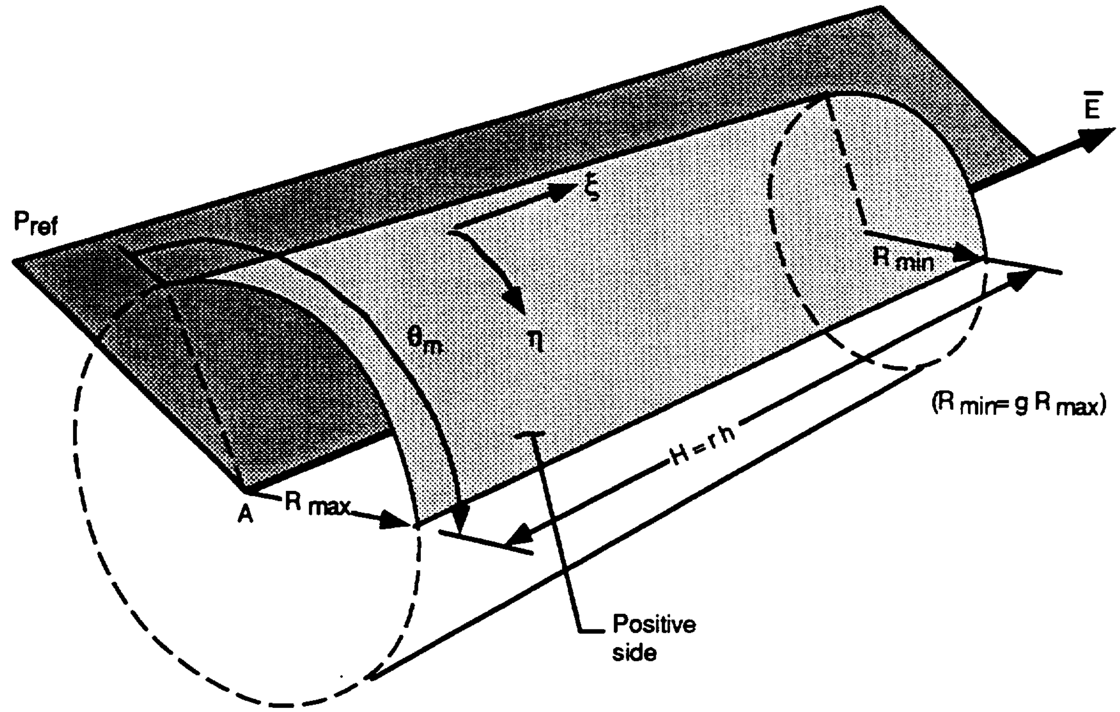

Figure 3.2.1-11. Cone Geometry Definition.

The trapezoid is described by three points P_1, P_2, and P_3 oriented as shown in figure 3.2.1-9 and the ratio

$$\lambda = \frac{|P_3 - P_4|}{|P_2 - P_1|} \qquad (3.2.1.38)$$

where $0 \le \lambda \le 1$ and $(P_2 - P_1) \| (P_3 - P_4)$. When P_1, P_2, and P_3 are oriented in clockwise order, the positive side of the trapezoid is visible. This is the normal right hand rule.

The cone and cylinder sections (figs. 3.2.1-10 and 3.2.1-11) and defined in similar manner because the cylinder is a special case of the cone. Point A is the center of the circle of radius R (cylinder) or R_{max} (cone) at the base of the cylinder or cone and normal to the axis. Vector **E** is parallel to and co-directed with the axis of the cone. h is the ratio the height H to R (cylinder) or R_{max} (cone). Reference point P_{ref} defines azimuthal angle $\theta = 0$ and θ is measured in the right hand direction about the axis vector **E**. θ_m is the maximum value of θ. For the cone R_{min} = g R_{max} where g is a dimensionless constant between 0 and 1. From this we see that the cylinder is a cone with g = 1.

The disk (fig. 3.2.1-12) is defined similarly to the cone with h deleted, R_{min} = r, and θ measured in the **left** hand direction about the axis vector **E**.

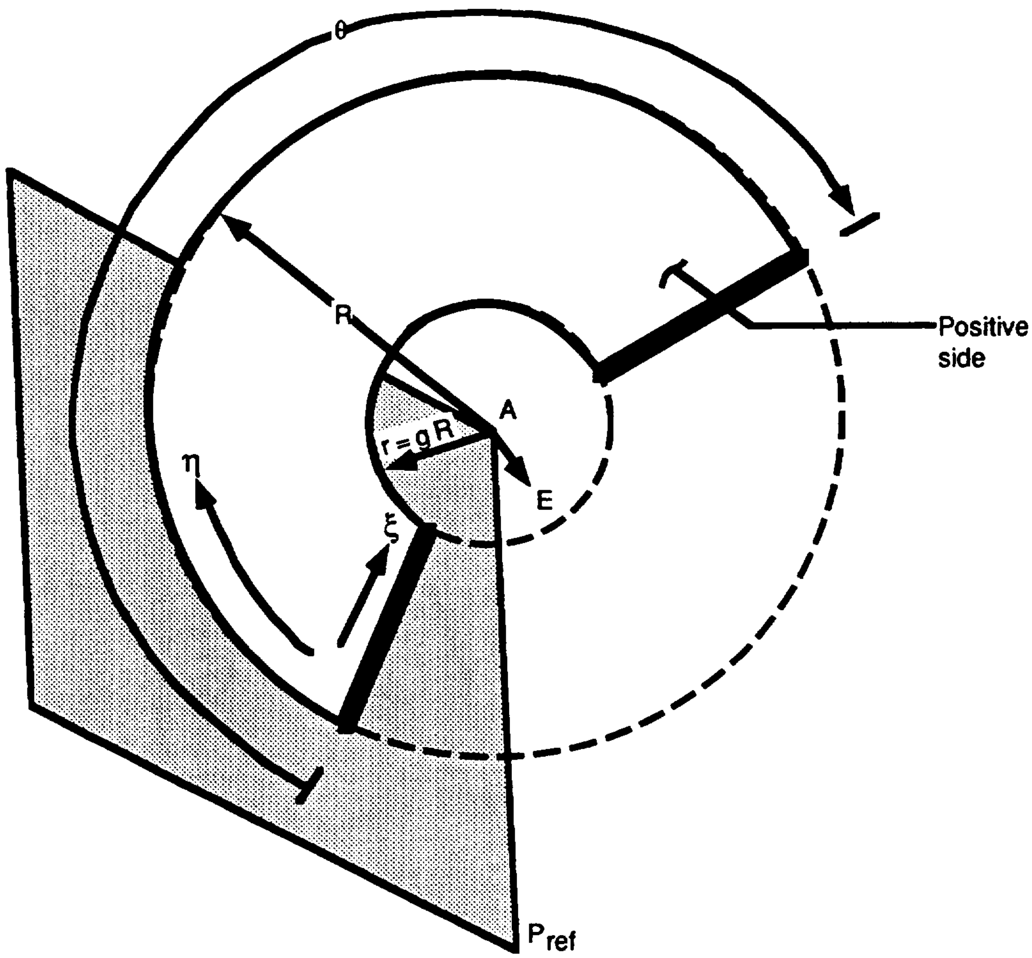

Figure 3.2.1-12. Disk Geometry Definition.

The sphere (fig. 3.2.1-13) is defined in similar manner to the cone with g and h deleted and bounding polar angles ϕ_1 and ϕ_2 added to define the polar extent of the sphere section. Vector **E** is co-directed with the half line $\phi = 0$.

A fundamental reference coordinate system for each primary surface is defined as follows.

For the trapezoid,

$$\mathbf{z} = \frac{(P_2 - P_1) \times (P_3 - P_1)}{|(P_2 - P_1) \times (P_3 - P_1)|} \tag{3.2.1.39}$$

$$\mathbf{y}_1 = \frac{(P_2 - P_1)}{|(P_2 - P_1)|} \tag{3.2.1.40}$$

$$\mathbf{y}_2 = \mathbf{z} \times \mathbf{y}_1 \tag{3.2.1.41}$$

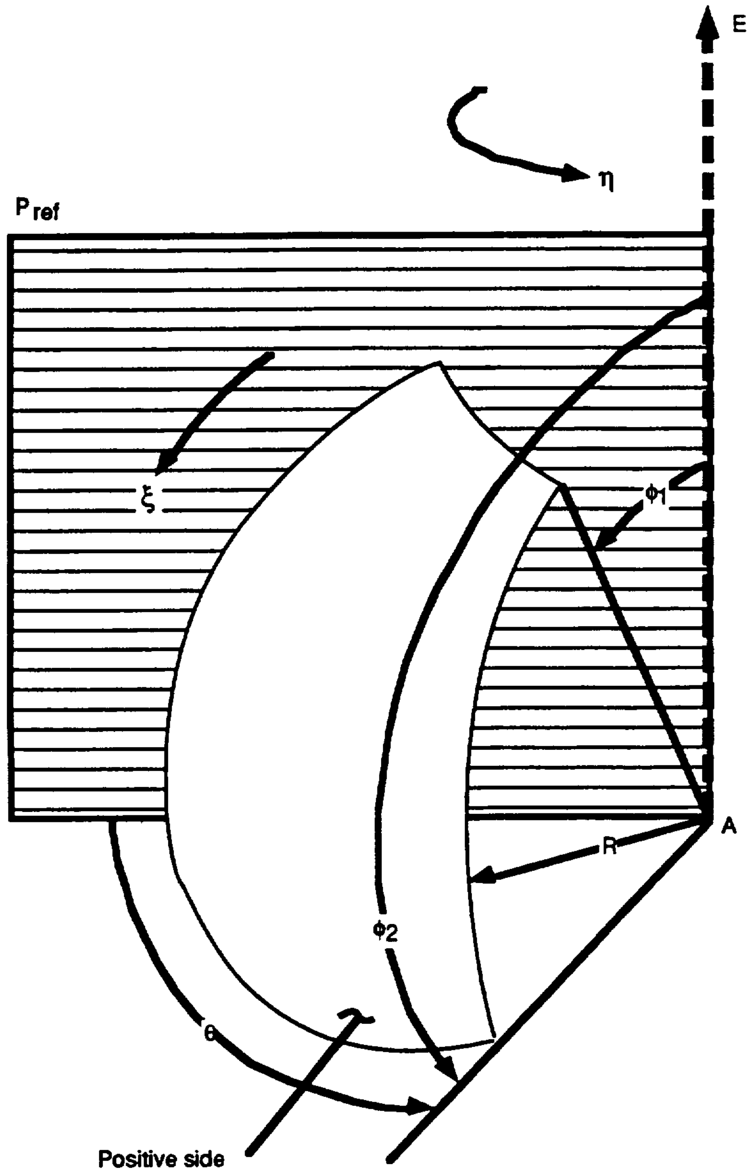

Figure 3.2.1-13. Sphere Geometry Definition.

and for the cylinder, cone, disk, and sphere,

$$\mathbf{z} = \frac{\mathbf{E}}{|\mathbf{E}|} \tag{3.2.1.42}$$

$$\mathbf{y}_2 = \frac{\mathbf{E} \times (P_{ref} - A)}{|\mathbf{E} \times (P_{ref} - A)|} \tag{3.2.1.43}$$

$$\mathbf{y}_1 = \mathbf{y}_2 \times \mathbf{z} \tag{3.2.1.44}$$

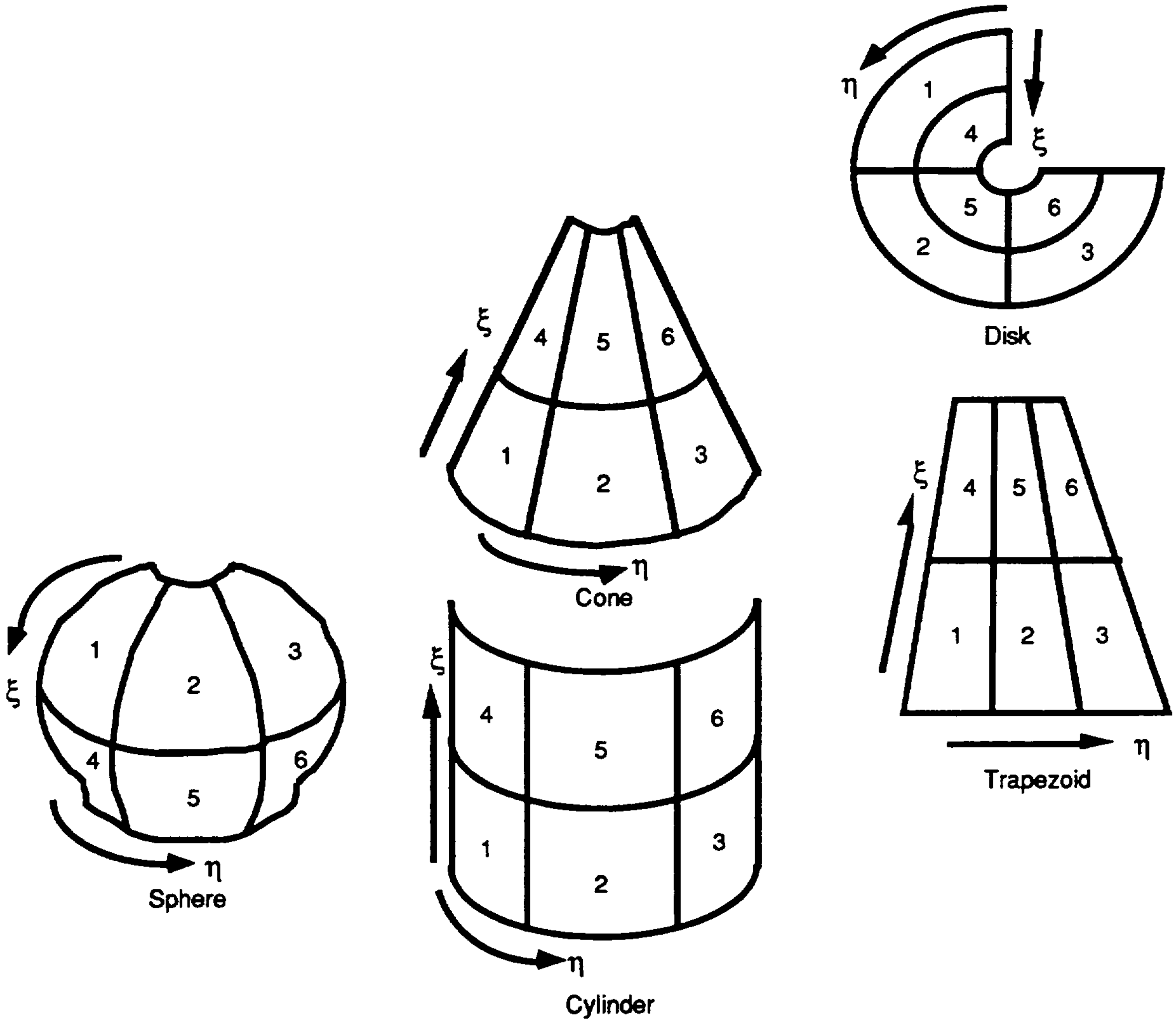

Figure 3.2.1-14. Node Arrangement on Surfaces.

To avoid numerical computation problems, the following restrictions are placed on the above definitions. For the trapezoid, the included angles between sides must be greater than c_A, where c_A is set to 0.1 degree in RAYG1. The latter requirement prevents two adjacent sides of the trapezoid from being parallel.

For the other primary surfaces, the magnitude of the angle included by (P_{ref} - A) and **E** must be less than c_A, where c_A is as defined above. Other variables used to define cylinders, cones, disks, and spheres are restricted to the following ranges:

$c_A < \theta_m < 360$ deg,

$0 < h < 1/\varepsilon_L$,

$0 \leq \phi_1 < \phi_2 < 180$ deg,

$\phi_2 - \phi_1 \geq 0$.

Surface points on each type of primary surface are defined in terms of input parameters and the dimensionless coordinates ξ and η. For the trapezoid a point P is located at

$$\begin{aligned} P &= P_1 + \eta(P_2 - P_1) + \xi[P_4 + \eta(P_3 - P_4) - P_1 - \eta(P_2 - P_1)] \\ &= P_1 + \xi(P_4 - P_1) + \eta(P_2 - P_1) + \xi\eta(P_1 - P_2 + P_3 - P_4) \end{aligned} \tag{3.2.1.45}$$

For the cylinder, cone, and disk

$$P = A + \xi r h \mathbf{z} + r\,\mathbf{y}[1 + \xi(g - 1)] \tag{3.2.1.46}$$

where g = 1 for a cylinder and h = 0 for a disk. For the sphere,

$$P = A + r[\mathbf{z}\cos\phi + \mathbf{y}\sin\phi] \tag{3.2.1.47}$$

In the above two equations,

$$\theta = \eta\theta_{max} \tag{3.2.1.48}$$

$$\phi = \phi_1 + \xi(\phi_2 - \phi_1) \tag{3.2.1.49}$$

$$\mathbf{y} = \mathbf{y}_1\cos\theta + \mathbf{y}_2\sin\theta \tag{3.2.1.50}$$

Differential areas dA for the five primary surface types may be expressed in terms of input parameters and ξ and η as follows. For the trapezoid

$$dA = [(P_2 - P_1)\cdot y_1]\,[(P_3 - P_1)\cdot y_2]\,[1 + (\lambda - 1)\,\xi]\,d\xi\,d\eta \tag{3.2.1.51}$$

For the cylinder, cone, and disk

$$dA = R^2\,\theta_m\,[h^2 + (g - 1)^2]^{1/2}\,[1 + (g-1)\,\xi]\,d\xi\,d\eta \tag{3.2.1.52}$$

with g = 1 for the cylinder and h = 0 for the disk. For the sphere

$$dA = R^2\,\theta_m\,(\phi_2 - \phi_1)\sin[\phi_1 + \xi(\phi_2 - \phi_1)]\,d\xi\,d\eta \tag{3.2.1.53}$$

Because an individual nodal surface is bounded by $\xi_1 < \xi < \xi_2$ and $\eta_1 < \eta < \eta_2$, the areas of nodal surfaces can be determined by integrating

$$A = \int_{\xi_1}^{\xi_2} d\xi \int_{\eta_1}^{\eta_2} d\eta\; dA\,(\xi,\eta) \tag{3.2.1.54}$$

which yields for the trapezoid

$$A = [(P_2 - P_1) \cdot y_1]\,[(P_3 - P_1) \cdot y_2]\,(\eta_2 - \eta_1)\,(\xi_2 - \xi_1)\,[1 + (\xi_2 + \xi_1)\,(\lambda - 1)/2] \qquad (3.2.1.55)$$

For the cylinder, cone, and disk

$$A = R^2\,\theta_m\,[h^2 + (g-1)^2]^{1/2}\,(\eta_2 - \eta_1)\,(\xi_2 - \xi_1)\,[1 + (\xi_2 + \xi_1)\,(g - 1)/2] \qquad (3.2.1.56)$$

with, as before, $g = 1$ for the cylinder and $h = 0$ for the disk. For the sphere

$$A = R^2\,\theta_m\,(\eta_2 - \eta_1)\,\{\cos[\phi_1 + \xi_1\,(\phi_2 - \phi_1)] - \cos[\phi_1 + \xi_2\,(\phi_2 - \phi_1)]\} \qquad (3.2.1.57)$$

Note that in equations (3.2.1.55) through (3.2.1.57) that the areas are directly proportional to η, but are nonlinear in ξ. Further, the expressions for area may be separated into three factors: a constant factor, the factor $(\eta_2 - \eta_1)$, and a ξ dependent factor $f(\xi_2, \xi_1)$. Thus, if the area of a node is known, the area of a portion of the node A_p bounded by $\eta_1 < \eta < \eta_p$, $\eta_p < \eta_2$, and $\xi_1 < \xi < \xi_2$ is given by

$$A_p = A\,(\eta_p - \eta_1)/(\eta_2 - \eta_1) \qquad (3.2.1.58)$$

Similarly if A_p bounded by $\eta_1 < \eta < \eta_2$ and $\xi_1 < \xi < \xi_p$, $\xi_p < \xi_2$,

$$A_p = A\,f(\xi_p, \xi_1)/f(\xi_2, \xi_1) \qquad (3.2.1.59)$$

A nodal surface is bounded by $\xi_1 < \xi < \xi_2$ and $\eta_1 < \eta < \eta_2$. It is desirable to determine the (ξ, η) position of a point given its relative position R_j and R_k on a nodal surface, where $0 \le R_j \le 1$ is in the η direction and $0 \le R_k \le 1$ is in the ξ direction.

$$R_j = (\eta - \eta_1)/(\eta_2 - \eta_1) \qquad \text{or} \qquad \eta = \eta_1 + R_j\,(\eta_2 - \eta_1) \qquad (3.2.1.60)$$

and

$$R_k = \frac{[1 + (p-1)\,\xi]^2 - [1 + (p-1)\,\xi_1]^2}{[1 + (p-1)\,\xi_2]^2 - [1 + (p-1)\,\xi_1]^2} \qquad (3.2.1.61)$$

or

$$\begin{aligned} \xi &= \xi_1 + R_k\,(\xi_2 - \xi_1) && \text{if } p = 1 \\ &= \frac{\left(1 - \sqrt{[1 + (p-1)\,\xi_1]^2 + R_k(\xi_2 - \xi_1)(p-1)[2 + (p-1)\,(\xi_2 - \xi_1)]}\right)}{1 - p} && \text{if } p \ne 1 \end{aligned} \qquad (3.2.1.62)$$

For the trapezoid, $p = \lambda$; for the cylinder, $p = 1$; for the cone and disk, $p = g$.

For the sphere,

$$R_k = \frac{\cos[\phi_1 + \xi_1(\phi_2 - \phi_1)] - \cos[\phi_1 + \xi(\phi_2 - \phi_1)]}{\cos[\phi_1 + \xi_1(\phi_2 - \phi_1)] - \cos[\phi_1 + \xi_2(\phi_2 - \phi_1)]} \tag{3.2.1.63}$$

or

$$\begin{aligned} \xi = \Big[&\cos^{-1}\big(\cos[\phi_1 + \xi_1(\phi_2 - \phi_1)] + \\ &R_k\{\cos[\phi_1 + \xi_2(\phi_2 - \phi_1)] - \cos[\phi_2 + \xi_1(\phi_2 - \phi_1)]\}\big) \\ &- \phi_1\Big] / (\phi_2 - \phi_1) \end{aligned} \tag{3.2.1.64}$$

To avoid the inverse cosine operation in the above equation and to simplify other calculations, it is convenient to rewrite the equation using the following change of variable

$$\frac{\cos\phi_1 - \cos[\phi_1 + \xi(\phi_2 - \phi_1)]}{\cos(\phi_1) - \cos(\phi_2)} \rightarrow \xi \tag{3.2.1.65}$$

Then

$$\cos\phi = \cos\phi_1 + \xi\big(\cos(\phi_2) - \cos(\phi_1)\big) \tag{3.2.1.66}$$

which leads to the following simplified equation for the sphere section which will be used hereafter

$$\xi = \xi_1 + R_k(\xi_2 - \xi_1) \tag{3.2.1.67}$$

<u>Generation of local unit normal and tangent vectors.</u> The unit normal vector **N** directed outward from the positive side of a nodal surface at point P corresponding to (ξ, η) on some primary surface and the orthogonal unit tangent vectors $\mathbf{T}_1$ and $\mathbf{T}_2$ are defined such that

$$\mathbf{T}_1 \times \mathbf{T}_2 = \mathbf{N} \tag{3.2.1.68}$$

Then, for the trapezoid and disk

$$\mathbf{N} = \mathbf{z}, \qquad \mathbf{T}_1 = \mathbf{y}_1, \qquad \mathbf{T}_2 = \mathbf{y}_2 \tag{3.2.1.69}$$

For the cone and cylinder, define

$$\cos\alpha = h / \sqrt{h^2 + (g-1)^2} \tag{3.2.1.70}$$

$$\sin\alpha = (1-g)/\sqrt{h^2 + (g-1)^2} \tag{3.2.1.71}$$

where g = 1 for the cylinder and g is the ratio of the minimum to the maximum radius for the cone. Then, for the cone and the cylinder

$$\mathbf{N} = \mathbf{y}\cos\alpha + \mathbf{z}\sin\alpha \tag{3.2.1.72}$$

$$\mathbf{T}_1 = -\mathbf{y}\sin\alpha + \mathbf{z}\cos\alpha \tag{3.2.1.73}$$

$$\mathbf{T}_2 = \mathbf{N} \times \mathbf{T}_1 = -\mathbf{y}_2\cos\theta + \mathbf{y}_1\sin\theta \tag{3.2.1.74}$$

and for the sphere

$$\mathbf{N} = \mathbf{z}\cos\phi + \mathbf{y}\sin\phi \tag{3.2.1.75}$$

$$\mathbf{T}_2 = -\mathbf{y}_2\cos\theta + \mathbf{y}_1\sin\theta \tag{3.2.1.76}$$

$$\mathbf{T}_1 = \mathbf{T}_2 \times \mathbf{N} = \mathbf{z}\sin\phi - \mathbf{y}\cos\phi \tag{3.2.1.77}$$

In the above equations θ, ϕ, and $\mathbf{y}$ are defined in equations (3.2.1.48) through (3.2.1.50).

<u>Ray tracing.</u> This section describes the method for determining whether a ray in a given direction from a point on a nodal surface intersects another surface, and, if so, whether that surface is the nearest surface intersected. Suppose L_m is the shortest ray length previously found from the point of origin P_0 and that the ray is co-directed with unit vector $\mathbf{v}$ to an intercept on some nodal surface. The problem is to consider some new primary surface and answer the following questions:

1. Does this ray intercept the primitive surface[7] containing primary surface of concern with positive intercept distance $L < L_m$? In practice it is desirable to require that $L > \varepsilon_L$, where ε_L is a small quantity of order 10^{-6}.

2. If so, is the intercept point within the primary surface?

3. If so, where within a nodal surface is the intercept point contained?

If the primitive surface is quadratic, that is, a cylinder, cone, or sphere, there will in general be two intercept points.The nearer one (the one with the shorter L) is considered first until one of the above questions has a negative answer, after which the sequence of questions is asked of the further point. If the first two questions have positive answers, the point of intercept is taken as

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[7] The primitive surface of a trapezoid or a disk section is the infinite plane which contains it. The primitive surface of a cylinder section is the complete infinite length cylinder. The primitive surface of a cone section is the complete infinite cone. The primitive surface of a sphere section is the complete sphere.

interim ray termination point P and L_m is replaced by L and the nodal surface within the primary surface is calculated. If the first question has a negative answer, the remaining questions need not be considered. The process is repeated until all primary surfaces have been considered.

The three questions are considered separately in the following subsections.

Does the ray intercept the primitive surface with $0 < L < L_m$? The intercept point P may be expressed

$$P = P_o + L\nu \tag{3.2.1.78}$$

Using equations (3.2.1.45) through (3.2.1.47) as appropriate to express P, this vector equation contains three scalar unknowns, L, ξ, and η. In dealing with this equation, it is convenient to introduce the quantity **B**,

$$\mathbf{B} = P_1 - P_o \tag{3.2.1.79}$$

for the trapezoid or

$$\mathbf{B} = \mathbf{A} - P_o \tag{3.2.1.80}$$

for cylinder, cone, disk, or sphere sections.

For the trapezoid and disk section primary surface types, taking the dot product of each side of equation (3.2.1.78) with the vector **z** gives directly

$$L(\nu \cdot \mathbf{z}) = (\mathbf{B} \cdot \mathbf{z}) \tag{3.2.1.81}$$

from which sign $(\mathbf{B}.\mathbf{z})$ = sign $(\nu.\mathbf{z})$ and the criterion $0 < L < L_m$ may be written as

$$0 < |\mathbf{B}\cdot\mathbf{z}| < L_m\,|\nu\cdot\mathbf{z}| \tag{3.2.1.82}$$

For the cylinder section or cone section primary surface types the calculations are more complex. Taking the dot product of each side of equation (3.2.1.78) with the vector **z** yields

$$\xi\, r\, h = L\,(\nu\cdot\mathbf{z}) - (\mathbf{B}\cdot\mathbf{z}) \tag{3.2.1.83}$$

Then, after rearranging equation (3.2.1.78) so that the term $r\, y\, [1 + \xi\, (g-1)]$ is alone on one side, squaring each side, and substituting for ξ using equation (3.2.1.83), there results

$$A\, L^2 - 2\, B\, L - C = 0 \tag{3.2.1.84}$$

where

$$A = 1 - (\nu\cdot\varepsilon)^2 \tag{3.2.1.85}$$

$$B = (\nu\cdot\mathbf{B}) - (\nu\cdot\varepsilon)\,[(B\cdot\varepsilon) - \delta] \tag{3.2.1.86}$$

$$C = (\mathbf{B}\cdot\varepsilon)\,[(\mathbf{B}\cdot\varepsilon) - 2\,\delta] + r^2 - \mathbf{B}\cdot\mathbf{B} \tag{3.2.1.87}$$

$$\varepsilon = \mathbf{z}\,(1+\gamma^2)^{1/2} \tag{3.2.1.88}$$

$$\delta = r\,\gamma\,(1+\gamma^2)^{1/2} \tag{3.2.1.89}$$

$$\gamma = (g - 1)/h \tag{3.2.1.90}$$

and $r = R$ for the cylinder and R_{max} for the cone.

For the sphere section primary surface type, after rearranging equation (3.2.1.78) so that the term $R\,[\mathbf{z} \cos\phi + \mathbf{y} \sin\phi]$ is alone on one side and squaring each side, there results similarly

$$A\,L^2 - 2\,B\,L - C = 0 \tag{3.2.1.91}$$

where $A = 1$, $B = (\nu\cdot\mathbf{B})$, $C = r^2 - \mathbf{B}\cdot\mathbf{B}$.

Thus, for all three quadratic primary surface types

$$L\,A = B \pm \sqrt{D} \tag{3.2.1.92}$$

with $D = B^2 + A\,C$.

Note that the vector ε and the scalar δ are independent of ray direction or point or origin. In stating a criterion for the existence of L such that $0 < L < L_m$, it is convenient to take A positive. The case $A = 0$ may be disregarded because its probability is negligibly small with ν chosen randomly. If $A < 0$, the quadratic equation (3.2.1.92) for L is preserved if the sign of each of the three coefficients A, B, and C is arbitrarily reversed, which will be assumed to have been done if necessary to make A positive.

Is P within the primary surface? In this subsection it is assumed that there does exist L such that $0 < L < L_m$ and that L has been calculated from equation (3.2.1.81), (3.2.1.83), or (3.2.1.92) as appropriate for the primary surface type. For all primary surface types but the disk section, the first step is to calculate the normalized coordinate ξ directly and to test for $0 < \xi < 1$. Only for the disk section primary surface type do computational savings result from an indirect calculation.

For the trapezoid primary surface type, taking the dot product of each side of equation (3.2.1.78) with unit vector $\mathbf{y}_2$ gives

$$\xi = \mathbf{w}\cdot(L\,\nu - \mathbf{B}) \tag{3.2.1.93}$$

where $\mathbf{w} = \mathbf{y}_2 / [\mathbf{y}_2 \cdot (P_4 - P_1)]$.

For the cylinder and cone section primary surface types, equation (3.2.1.83) can be rewritten as

$$\xi = \mathbf{w} \cdot (L\,\nu - \mathbf{B}) \tag{3.2.1.94}$$

where $\mathbf{w} = \mathbf{z} / (r\,h)$.

For the disk section primary surface type, inspection of (3.2.1.78) (noting that $h = 0$) shows that

$$|L\,\nu - \mathbf{B}| = R\,[1 + \xi\,(g-1)] \tag{3.2.1.95}$$

or

$$\xi = [1 - |L\,\nu - \mathbf{B}|\,/R]\,/\,(1 - g) \tag{3.2.1.96}$$

For this primary surface type the criterion $0 < \xi < 1$ is most conveniently applied in the form

$$R^2 > L^2 + \mathbf{B} \cdot \mathbf{B} - 2\,L\,(\nu - \mathbf{B}) > R^2\,g^2. \tag{3.2.1.97}$$

For the sphere section primary surface type, taking the dot product of each side of equation (3.2.1.78) with unit vector $\mathbf{z}$ yields

$$\cos\phi = \mathbf{z} \cdot (L\,\nu - \mathbf{B})\,/\,R \tag{3.2.1.98}$$

which, upon use of equation (3.2.1.66), becomes

$$\xi = v - \mathbf{w} \cdot (L\,\nu - \mathbf{B}) \tag{3.2.1.99}$$

where $\mathbf{w} = \mathbf{z} /[R\,(\cos\phi_1 - \cos\phi_2)]$ and $v = \cos\phi_1 / (\cos\phi_1 - \cos\phi_2)$.

If $0 < \xi < 1$, then the second step, determining if $0 < \eta < 1$, is carried out. It is assumed that both L and ξ have been evaluated.

For the trapezoid primary surface type, taking the dot product of each side of equation (3.2.1.78) with $\mathbf{y}_1$ and noting the definition of the length ratio λ yields

$$\eta\,[1 + \xi\,(\lambda - 1)] = \mathbf{u} \cdot (L\,\nu - \mathbf{B}) - v\,\xi \tag{3.2.1.100}$$

where $\mathbf{u} = \mathbf{y}_1 / [\mathbf{y}_1 \cdot (P_2 - P_1)]$ and $v = \mathbf{y}_1 \cdot (P_4 - P_1) / [\mathbf{y}_1 \cdot (P_2 - P_1)]$.

For the other four primary surface types, equation 3.2.1.78 is solved for $\cos\theta$ through dot multiplication by $\mathbf{y}_1$ and for $\sin\theta$ through dot multiplication by $\mathbf{y}_2$. The solutions are

$$[1 + \xi\,(g - 1)]\cos\theta = \mathbf{Y}_1 \cdot (L\,\nu - \mathbf{B}) \tag{3.2.1.101}$$

$$[1 + \xi\,(g - 1)]\sin\theta = \mathbf{Y}_2 \cdot (L\,\nu - \mathbf{B}) \tag{3.2.1.102}$$

where $Y_1 = y_1 / r$ and $Y_2 = y_2 / r$ and $r = R$ or R_{max} depending on surface type. Then, $0 < \eta < 1$ if $\sin\theta_m \geq 0$ and $\sin\theta > 0$ and $\cos\theta > \cos\theta_m$ or if $\sin\theta_m < 0$ and $\sin\theta > 0$ or $\cos\theta < \cos\theta_m$.

Within what nodal surface is P? It is assumed in this subsection that ξ and η have already been calculated and that the number of nodes in the ξ direction NC and the number of nodes in the η direction NN for the primary surface are known. The primary surface is a square in (ξ, η) space, that is, $0 < \xi < 1$ and $0 < \eta < 1$, and each nodal surface is a rectangle in (ξ, η) space bounded by $0 \leq \xi_1 < \xi < \xi_2 \leq 1$ and $0 \leq \eta_1 < \eta < \eta_2 \leq 1$. Each nodal surface on a primary surface is given an index number. Figure 3.2.1-14 shows the arrangement of nodal surfaces on each of the five primary surfaces for NC = 2 and NN = 3. The position of ξ in terms of nodal surfaces within the primary surface is given by

$$N_\xi = (\xi \; NC) \tag{3.2.1.103}$$

where the term in parenthesis is rounded up to the next integer. The position of η in terms of nodal surfaces within the primary surface is given by

$$N_\eta = (\eta \; NN) \tag{3.2.1.104}$$

where again the term in parenthesis is rounded up to the next integer. Now, given the nodal surface coordinates as N_ξ and N_η, the index IN of the nodal surface containing ξ and η is given by

$$IN = N_\eta + NN\,(N_\xi - 1). \tag{3.2.1.105}$$

Two-Dimensional Interpolation. AO fluxes are calculated at the (ξ,η) centers of the nodes on surfaces. However, for proper display during plotting, fluxes are needed near the corners of the nodes[8]. The following scheme interpolates fluxes from the (ξ,η) centers of the nodes to the corners of the nodes. It is most convenient to perform the interpolation in (ξ,η) space rather than in Cartesian (x,y,z) coordinates.

As noted previously, each surface is a square in (ξ,η) space with $0 \leq \xi \leq 1$ and $0 \leq \eta \leq 1$. For a surface divided into NC equal nodes in the ξ direction and NN equal nodes in the η direction, the dimensions of each nodes are 1/NC in the ξ direction and 1/NN in the η direction. The node centers are at $({}^c\xi_j, {}^c\eta_i) = ([j\text{-}0.5]/NC, [i\text{-}0.5]/NN)$ with j = 1,2,...,NC and i = 1,2,...,NN. Figure 3.2.1-15 shows a typical surface representation in (ξ,η) space with NC = 2 and NN = 3. The figure also shows the location of the points near the corners of the nodes, whose values of fluxes are to be interpolated. Inspection of the figure shows that only two of the points whose values are to be interpolated lie within the perimeter of the points at the centers of the nodes

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[8]To avoid ambiguity in node assignment, the points "near the corners" are chosen to be set in from the corners by 1% of the node dimension. Hereafter, references to the corners of nodes will be synonymous with "near the corners."

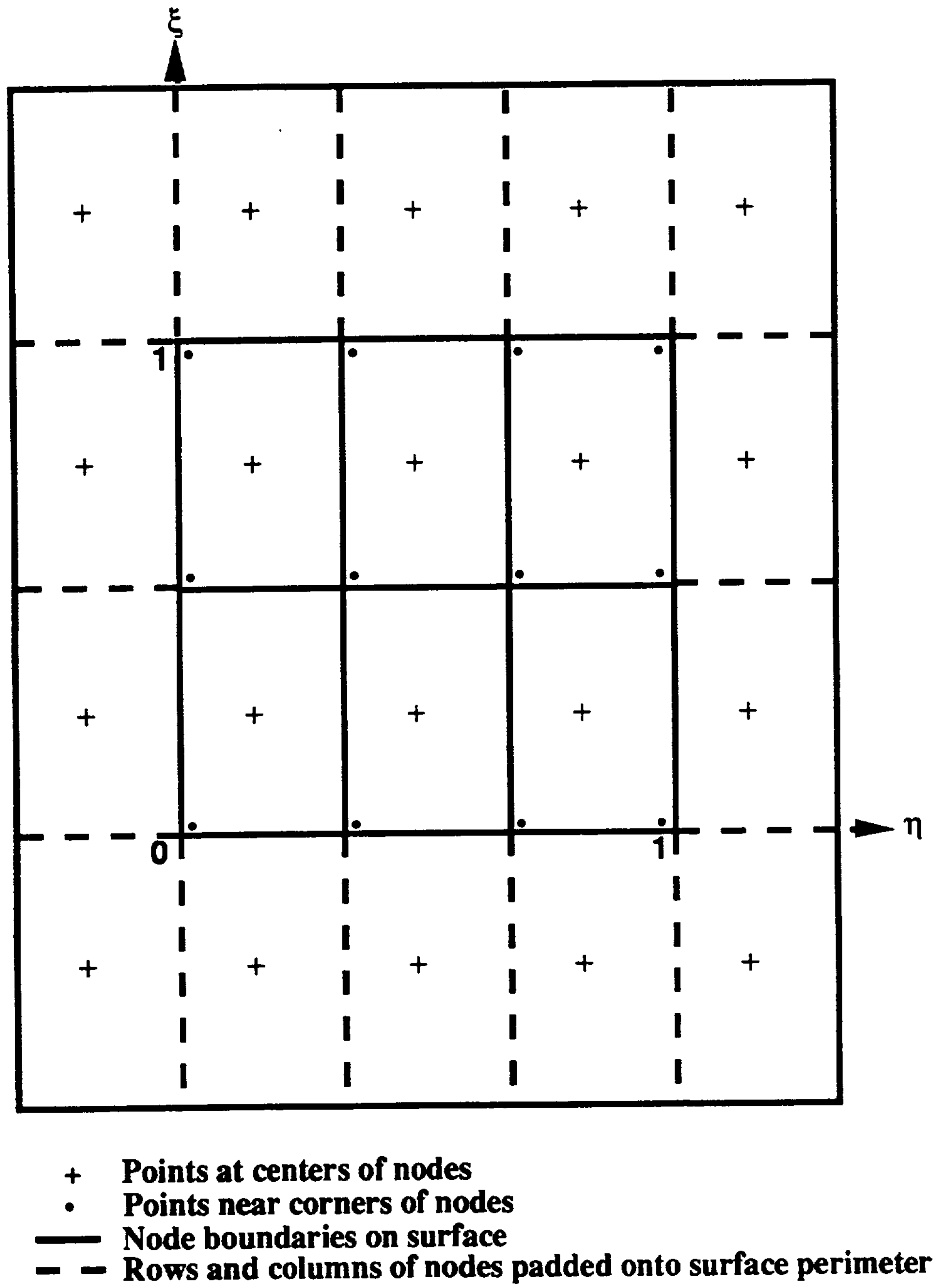

Figure 3.2.1-15. Surface in (ξ,η) Space With NC = 2, NN = 3.

Because extrapolation is, in general, less accurate than interpolation, the edges of open surfaces[9] are padded with extra rows and columns as follows: The lower edge is padded by repeating the

[9]An open surface is defined as one such that the Cartesian coordinates of (ξ,η = 0) and (ξ,η = 1) are different, for example, a trapezoid. A closed surface is defined as one such that the Cartesian coordinates of (ξ,η = 0) and (ξ,η = 1) are identical; for example, an annulus of a cylinder or of a sphere.

fluxes values for ${}^{c}\xi_j$ below the surface and the top edge by repeating the fluxes values for ${}^{c}\xi_{NC}$ above the surface. The left and right edges are padded using the fluxes values for ${}^{c}\eta_i$ and ${}^{c}\eta_{NN}$, respectively; and the corners by repeating the fluxes values at the corresponding node centers at the corners of the surface. Closed surfaces are padded in similar manner except that the left column is padded with fluxes values of the ${}^{c}\eta_{NN}$ column and the right column with fluxes values from the ${}^{c}\eta_1$ column. The centers of the nodes added for padding are at (${}^{c}\xi_j$, ${}^{c}\eta = -0.5/NN$) and (${}^{c}\xi_j$, ${}^{c}\eta = 1 + 0.5/NN$) for the left and right columns, respectively, and (${}^{c}\xi = -0.5/NC$, ${}^{c}\eta_i$) and (${}^{c}\xi = 1 + 0.5/NC$, ${}^{c}\eta_i$) for the bottom and top rows, respectively.

These preliminaries concluded, the description of the interpolation algorithm may begin. Suppose one wishes to interpolate the the value of fluxes $y(\xi,\eta)$ at (ξ,η), given that ${}^{c}\xi_j \le \xi \le {}^{c}\xi_{j+1}$ and ${}^{c}\eta_i \le \eta \le {}^{c}\eta_{i+1}$. The interpolation is performed in two steps. First, one-dimensional interpolations are performed on the rows for each ${}^{c}\xi_j$ row, $1 \le j \le NC$, to give the one-dimensional array of fluxes $({}^{c}\xi_j|\eta)$ where $({}^{c}\xi_j|\eta)$ indicates that η is fixed. Then, this array is interpolated to give the value of fluxes at ξ.

The interpolation scheme used is Stineman's consistently well-behaved method of interpolation (ref.10). The following explanation of the method quotes parts of reference 10 directly except for changes of equation and figure numbers to be consistent with this document and additions and deletions specific to the problem addressed by this document.

The interpolation scheme has the following three properties. First, if values of the ordinates of adjacent specified points (the fluxes at the node centers in the ξ or η direction) change monotonically and the slopes of the line segments joining the points change monotonically, then the interpolating curve and its slope will change monotonically. Second, if the slopes of the line segments joining the adjacent points change monotonically, then the slope of the interpolating curve will change monotonically. Third, suppose that the first two conditions are satisfied by a set of points, but that a small change in the ordinate or slope at one of the points will result in one of the conditions no longer being satisfied. Then, making this small change in the ordinate or slope at a point will cause no more than a small change in the interpolating curve.

The interpolation scheme is implemented as follows. Assume that the ordered sequence of data (x_j, y_j), $j = 1, 2, \ldots, n$ is given where (x_j, y_j) are the rectangular coordinates of the j^{th} point on the curve (here x_j may be either ${}^{c}\xi_j$ or ${}^{c}\eta_i$ and n may be NC + 2 or NN + 2 as appropriate and y_j is the corresponding fluxes). Let y_j' be the slope of the curve at the j^{th} point and require that $x_j < x_{j+1}$ for $j = 1, 2, \ldots, n-1$. Calculation of y_j' will be considered presently. Before doing so, it is noted that the y_j' are calculated most accurately if the x_j and y_j have roughly equal ranges. To ensure this, the values of ${}^{c}\xi_j$, ${}^{c}\eta_i$ and fluxes(${}^{c}\xi_j$, ${}^{c}\eta_i$) are each scaled to be in the range 0 to 1 before interpolation begins. After completion of interpolation, the interpolated y are rescaled back to their true values.

Given x such that $x_j \le x \le x_{j+1}$, the procedure for calculating y (the corresponding interpolated value) is the following. The slope of the line segment joining the two points is

$$s_j = \frac{y_{j+1} - y_j}{x_{j+1} - x_j} \tag{3.2.1.106}$$

On the line segment the ordinate corresponding to x is

$$y_o = y_j + s_j\,(x - x_j) \tag{3.2.1.107}$$

Next,

$$\Delta y_j = y_j + y_j'\,(x - x_j) - y_o \tag{3.2.1.108}$$

where Δy_j is the vertical distance from the point (x, y_o) to a line through (x_j, y_j) with slope y_j', as shown in figure 3.2.1-16. Similarly,

$$\Delta y_{j+1} = y_{j+1} + y_{j+1}'\,(x - x_{j+1}) - y_o \tag{3.2.1.109}$$

is the vertical distance from the point (x, y_o) to a line through (x_{j+1}, y_{j+1}) with slope y_{j+1}', also shown in figure 3.2.1-16. The product $\Delta y_j\,\Delta y_{j+1}$ is then calculated and tested.

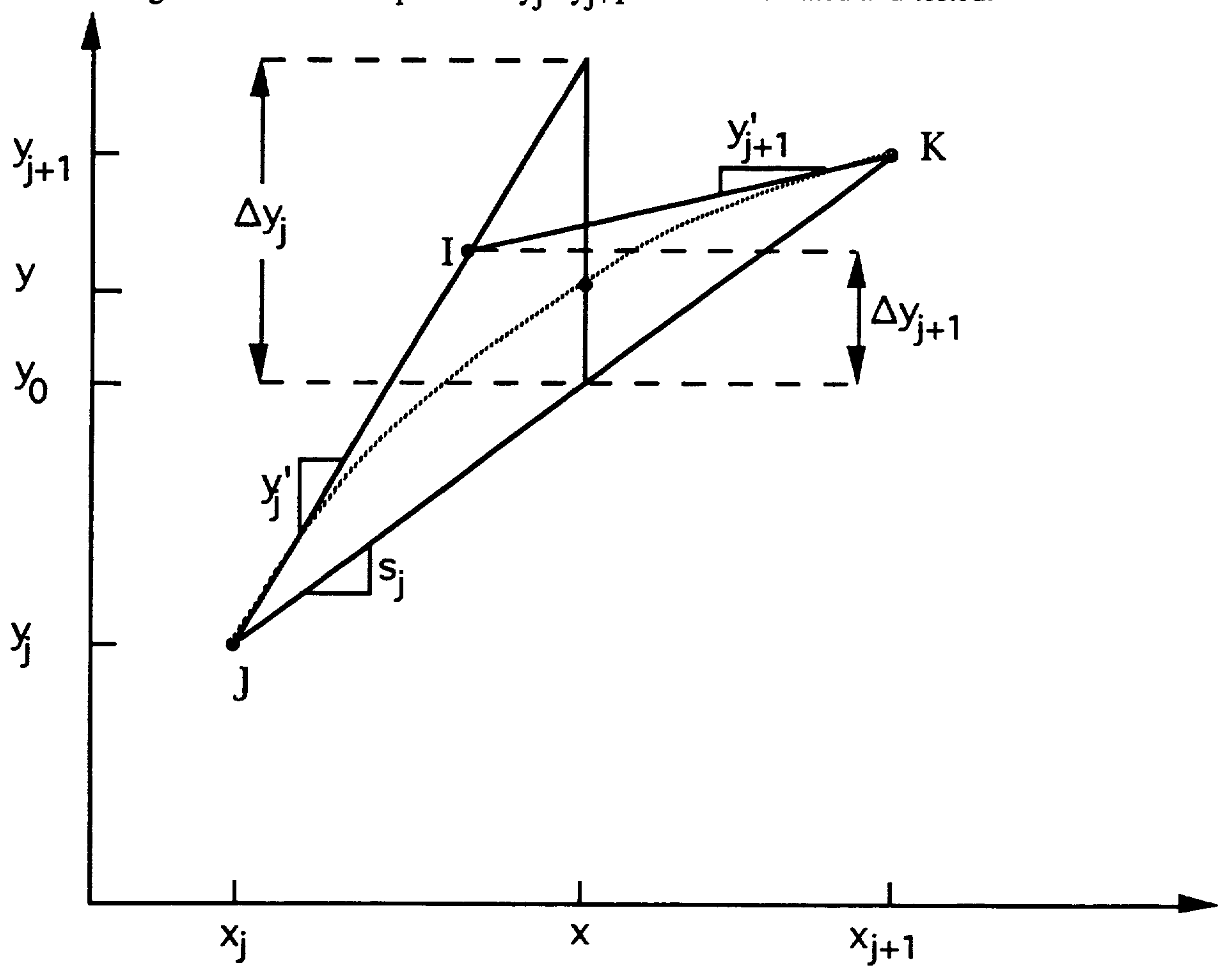

Figure 3.2.1-16. Consistently Well-Behaved Interpolation for $\Delta y_j\,\Delta y_{j+1} > 0$.

If $y_j' = s_j$, then the line through point (x_j, y_j) will coincide with the line segment joining points (x_j, y_j) and (x_{j+1}, y_{j+1}), and $\Delta y_j = 0$. Similarly, if $y_{j+1}' = s_j$, then $\Delta y_{j+1} = 0$. If either or both Δy_j or Δy_{j+1} are zero, then the product $\Delta y_j \, \Delta y_{j+1} = 0$ and y is simply

$$y=y_o \tag{3.2.1.110}$$

If $\Delta y_j \, \Delta y_{j+1} > 0$, then (as in fig. 3.2.1-16) Δy_j and Δy_{j+1} have the same sign, and

$$y = y_o + \frac{\Delta y_j \, \Delta y_{j+1}}{\Delta y_j + \Delta y_{j+1}} \tag{3.2.1.111}$$

Equation (3.2.1.111) always determines the point (x, y) inside the triangle IJK of figure 3.2.1-16. The slope of the interpolating curve matches the given slopes at the given points. The slope changes monotonically between x_j and x_{j+1}, so the interpolating curve is always concave toward the line segment joining the two points.

If $\Delta y_j \, \Delta y_{j+1} < 0$, then the geometry is as in figure 3.2.1-17 and there must be an inflection point between x_j and x_{j+1}. In this case,

$$y = y_o + \frac{\Delta y_j \, \Delta y_{j+1} \, (x - x_j + x - x_{j+1})}{(\Delta y_j - \Delta y_{j+1}) \, (x_{j+1} - x_j)} \tag{3.2.1.112}$$

Equation (3.2.1.112) always determines the point (x, y) inside the quadrilateral JIKL of figure 3.2.1-17, where the vertical distance LO equals the vertical distance OI. The slope of the interpolating curve matches the slopes at the given points x_j and x_{j+1}. The interpolating curve intersects the line segment JK at its midpoint.

The rationale for equation (3.2.1.112) may be understood by considering the case where y_j is significantly greater than s_j, the slope of line segment JK, but y_{j+1} is nearly equal to s_j (fig. 3.2.1-16 or 3.2.1-17). Regardless of whether y_{j+1} is greater or less than s_j, points I and L will be very close to point J and the interpolating curve will be very close to line segment JK. Thus, a change of y_{j+1} from slightly more than s_j to slightly less than s_j will cause only a slight change in the interpolating curve. This illustrates the third property, described above, of the interpolation scheme .

The derivatives y_j' are calculated by the following procedure, which ensures that they have the properties required by the interpolation method. In figure 3.2.1-18 let I, J, and K be any three consecutive points. Point J may be above or below the line segment joining I and K as shown in figures 3.2.1-18a and 3.2.1-18b, respectively. The requirements on the derivatives are satisfied if y_j' has a value between the slopes of the line segments IJ and JK. That is, for figure 3.2.1-18a, it is necessary that slope(IJ) > y_j' > slope(JK), while for figure 3.2.1-18b, slope(IJ) < y_j' < slope(JK). Another point is that if, for example, line segment IJ is much shorter then JK, it may easily be seen that a smoother overall interpolation curve will result if y_j' is nearly equal to the slope of IJ.

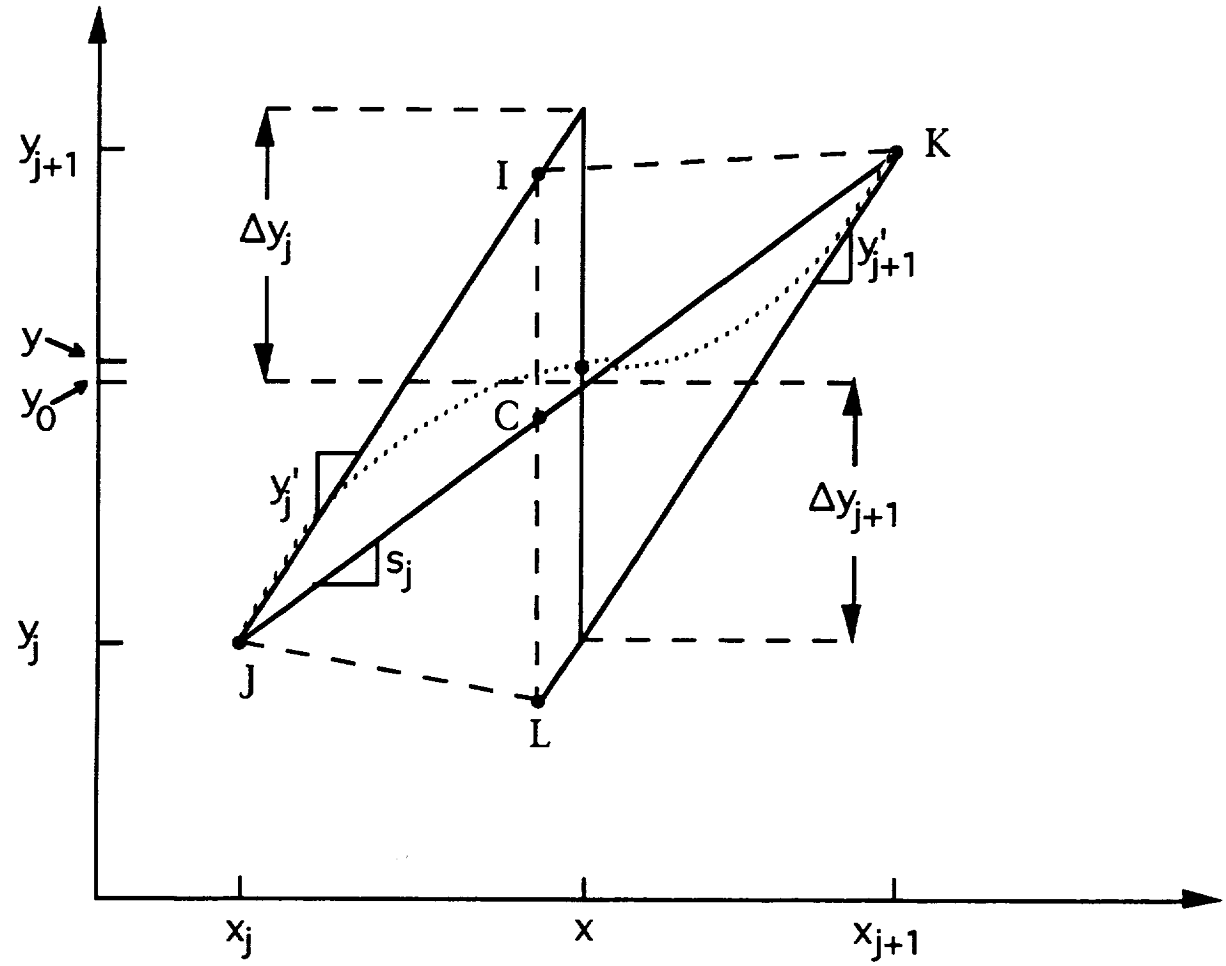

Figure 3.2.1-17. Consistently Well-Behaved Interpolation for $\Delta y_j \, \Delta y_{j+1} < 0$.

All of the above considerations are satisfied by setting y_j' equal to the slope at point J of a circle through points I and K. Thus,

$$y_j' = \frac{(y_j - y_i)\left((x_k - x_j)^2 + (y_k - y_j)^2\right) + (y_k - y_j)\left((x_j - x_i)^2 + (y_j - y_i)^2\right)}{(x_j - x_i)\left((x_k - x_j)^2 + (y_k - y_j)^2\right) + (x_k - x_j)\left((x_j - x_i)^2 + (y_j - y_i)^2\right)} \qquad (3.2.1.113)$$

Equation (3.2.1.113) takes care of all interior points. The end points require special attention. From the requirements on the y_j' it may be seen that the slope at an end point must have the same sign as the line segment from the end point to the next point. In line with the use of equation (3.2.1.113), one might draw a circle through the first (or last) three points. However, if either point I or K of figure 3.2.1-18 is an end point, the particular arrangement of the points causes the slope of the circle at I or K to have the wrong sign. The sign of the slope is not necessarily wrong at the end point, but it may be wrong.

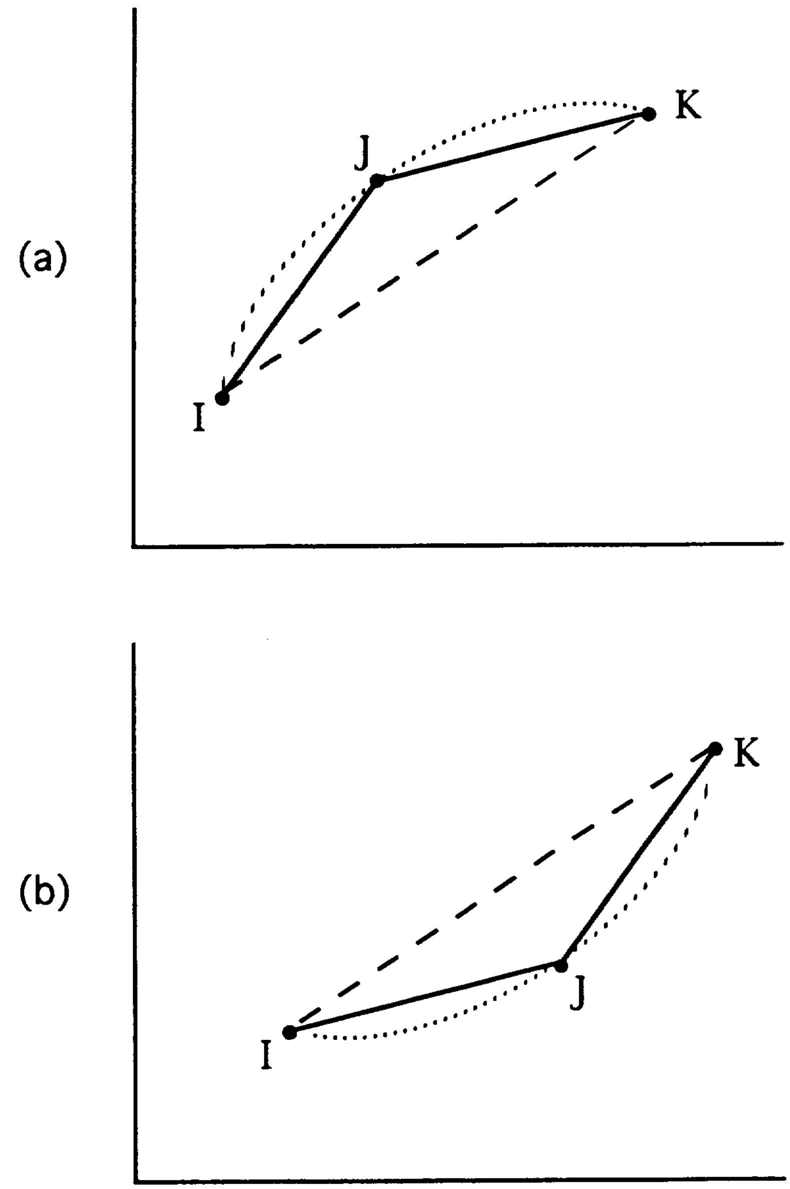

Figure 3.2.1-18. Calculation of Derivatives.

The problem divides into two cases. To simplify the notation, let M and subscript m designate either point I or K, whichever is an end point, and let s be the slope of the line segment joining points J and M. The first case occurs when s is steeper than y_j'. In this case, a parabola through J and M with slope y_j' at J has a slope at M which meets the requirements and is reasonable. Stated more precisely, if $s > 0$ and $s > y_j'$ or if $s < 0$ and $s < y_j'$, then

$$y_m' = s + (s - y_j') = 2s - y_j' \qquad (3.2.1.114)$$

The second case occurs if neither condition for the first case is satisfied. In this case, the term in parenthesis in equation (3.2.1.114) is multiplied by a factor between zero and one which assures that y_m' is always the same sign as s. The result is

$$y_m' = s + \frac{|s|\,(s - y_i')}{|s| + |s - y_i'|} \tag{3.2.1.115}$$

3.2.2 MDDB Algorithm

The primary mode of operation of MDDB is one of interactive prompt and user response to the prompts. Major computational routines to specify the positions of points on surfaces for TECPLOT display are CONNECM, RAYG1M, RAYG2M, and RAYG3M. These are modified versions of subroutines of similar name in SHADOW. Users interested in the algorithms used in these routines should refer to the algorithm descriptions in section 3.2.1.

3.2.3 Average Exposure Conditions

The microenvironments program requires inputs of average atomic oxygen number density and average temperature for the atmosphere. The average velocity of the vehicle relative to the atmosphere is also required. These averages must be calculated for the time period over which the microenvironments model is to be applied.

A means of obtaining these average exposure inputs (number density, temperature, and relative velocity) using the direct atomic oxygen exposure model has been devised. The method yields average exposure inputs that take into account all of the factors affecting exposure handled by the direct atomic oxygen exposure model. These factors are summarized in figure 3.2.3-1. Further details of the primary atomic oxygen model are presented in reference 1.

All of the factors shown in figure 3.2.3-1 significantly affect exposure. Orbit altitude and atmospheric conditions are especially important. At an altitude of 400 km, a 25 km decrease in altitude causes atomic oxygen density to increase by 50%. At this same altitude, atomic oxygen densities may differ by a factor of 20 between maximum and minimum conditions of solar activity.

These wide swings in the severity of the exposure environment make it necessary to integrate atomic oxygen rates with time to determine precise exposures. It is not considered practical to add further to the complications of the calculation by linking microenvironment variables directly to integrations involving variations in the atmosphere and vehicle orbit parameters. The solution to this complex problem is to handle the determination of exposure conditions and the microenvironments model calculation in succession. Fluences to surfaces of a spacecraft that do not interfere with each other can be calculated efficiently with the primary model while treating the variables shown in figure 3.2.3-1. The results of the primary exposure calculation are then used to define average exposure conditions for a mission or a pertinent portion of a mission. These constant average conditions of exposure become inputs for the microenvironments model.

The calculation of average conditions from fluences to non-interfering surfaces of a vehicle is very straightforward once the primary exposure model has been applied. The required formulas for the calculation of average conditions are readily derived from equation (8) in reference 1. Resulting equations for the average conditions are as follows:

$$F_0 = \text{(Fluence in ram direction)/(Time for event or mission)} \tag{3.2.3.1}$$

$$F_{90} = (\text{Fluence } 90° \text{ to ram direction})/(\text{Time for event or mission}) \tag{3.2.3.2}$$

$$N_{Average} = F_0/(\text{Average orbital speed}) \tag{3.2.3.3}$$

$$<c> = 4F_{90}/N_{Average} \tag{3.2.3.4}$$

$$T_{Average} = (\pi M/8R) <c>^2 \tag{3.2.3.5}$$

where

$<c>$	Average molecular speed, cm/sec
F	Atomic oxygen flux, atoms/cm^2-sec
M	Molecular weight of oxygen, 16.00 g/g-mole
N	Number density, molecules/cm^3
R	Universal gas constant, 8.314 x 10^7 ergs/g-mole-K°
T	Absolute temperature, K°
π	Value of pi, 3.14 . . .

Averages for atomic oxygen number density, atmospheric temperature, and orbital speed together with parameters describing the geometry and surface properties of the vehicle hardware become the inputs for the atomic oxygen microenvironments model.

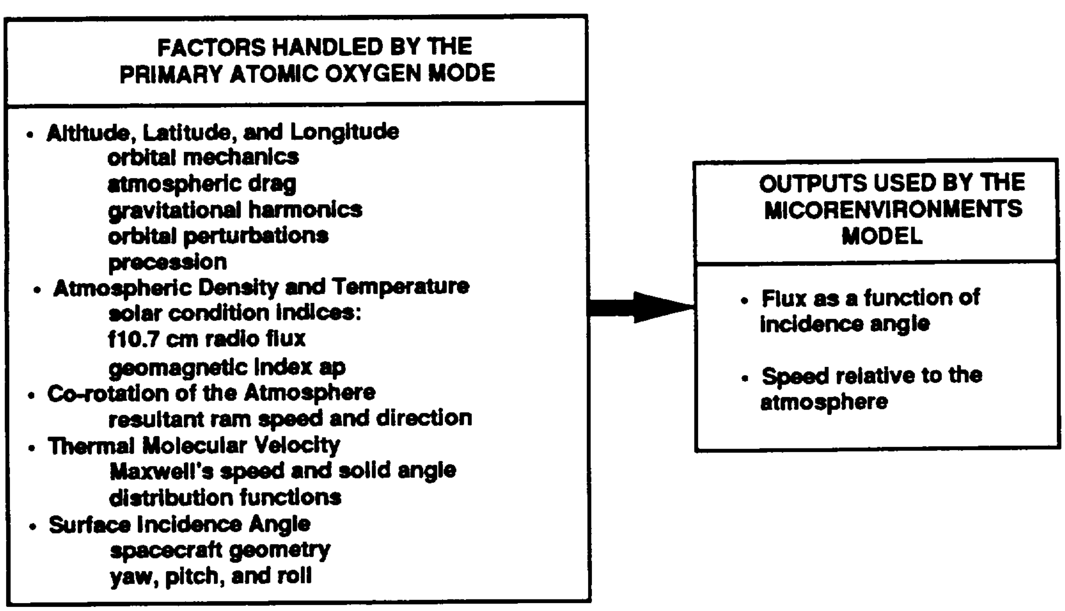

Figure 3.2.3-1. Factors Accounted for by the Direct Atomic Oxygen Exposure Model.

REFERENCES

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4. R.J. Bourassa, H.G. Pippin, and J.R. Gillis, *Model of Spacecraft Atomic Oxygen and Solar Exposure Microenvironments,* Presented at the LDEF Materials Results for Spacecraft Applications Conference, October 1992, Huntsville, Alabama.

5. R.J. Bourassa, H.G. Pippin, and J.R. Gillis, *LDEF Microenvironments, Observed and Predicted,* Second Post-Retrieval Symposium, June 1992, pg 13.

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8. T. S. Tsein, *Superaerodynamics, Mechanics of Rarefied Gases*, J. Aero. Sci. **13**, 653-664 (1946).

9. R. C. Corlett, private communication (1993).

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APPENDIX A: SAMPLE PROGRAM RUN

Appendix A contains a series of sample files that have been constructed by taking a sample geometry and running it through the entire process to its final output. The sample geometry structure was devised so that each of the five primary surface types is used once and so that, when SHADOWV2 is run, the effects of multiple reflections are apparent. The active side of the sphere, cone, and cylinder are on the outside. The active side of the disk and the trapezoid are toward the center of the structure. The surfaces have a variety of different surface properties. The ram direction (direction of the satellite velocity vector) is along the positive z axis; that is, from the center of the disk and pointing through the point of the cone. The atomic oxygen density and atmospheric temperature were chosen to be one month of low Earth orbit conditions.

A.1 3D Graph of Surfaces

Figure A1 is a black and white image of an MDDB TECPLOT color display of the sample file geometry. (The structure has been rotated from its original position so that it can be viewed more clearly.) An MDDB TECPLOT display will be colored as labeled in figure A1. The active side of each surface is indicated by a surface normal direction arrow. The direction arrow for the blue square is not visible because it points down into the sphere.

When the structure is viewed from the top, the intersection of the sphere and square is an example of where TECPLOT sometimes draws lines where it is not supposed to. (See section 2.2.3 about problems with TECPLOT.) However, this is not shown in Figure A1.

A.2 Input File Generated by MDDB

This is the file generated by MDDB. Note that the cone ratio is taken to be 0.001 instead of 0.000, and the sphere azimuthal angles range from 0.001 to 179.9999, instead of 0 to 180 degrees. (See sec. 2.2.3 about problems with TECPLOT.)

File on PC: sample0.shd

```
Sample geometry with 5 surfaces.
 EVENT START DATE      Unknown
 EVENT END DATE        Unknown
Unknown
SHADOWV2 sample file
 1    5    5 T T T
            -4.0000              -4.0000              15.0000
            -4.0000               4.0000              15.0000
             4.0000               4.0000              15.0000
                                                       1.0000
PLANE
PLANE MATERIAL
    300.00     .5000     .5000     .0000     .0000     SP,DIF,RE,SR
 2    5   24 T T T
              .0000                .0000               1.0000
              .0000                .0000                .0000
             1.0000                .0000                .0000
             3.0000               1.6667                                 360.0000
CYLINDER
CYLINDER MATERIAL
    300.00     .2500     .7000     .0500     .0000     SP,DIF,RE,SR
 3    6   24 T T T
              .0000                .0000               1.0000
              .0000                .0000               5.0000
             1.0000                .0000                .0000
             3.0000               1.6667                .0010            360.0000
CONE
```

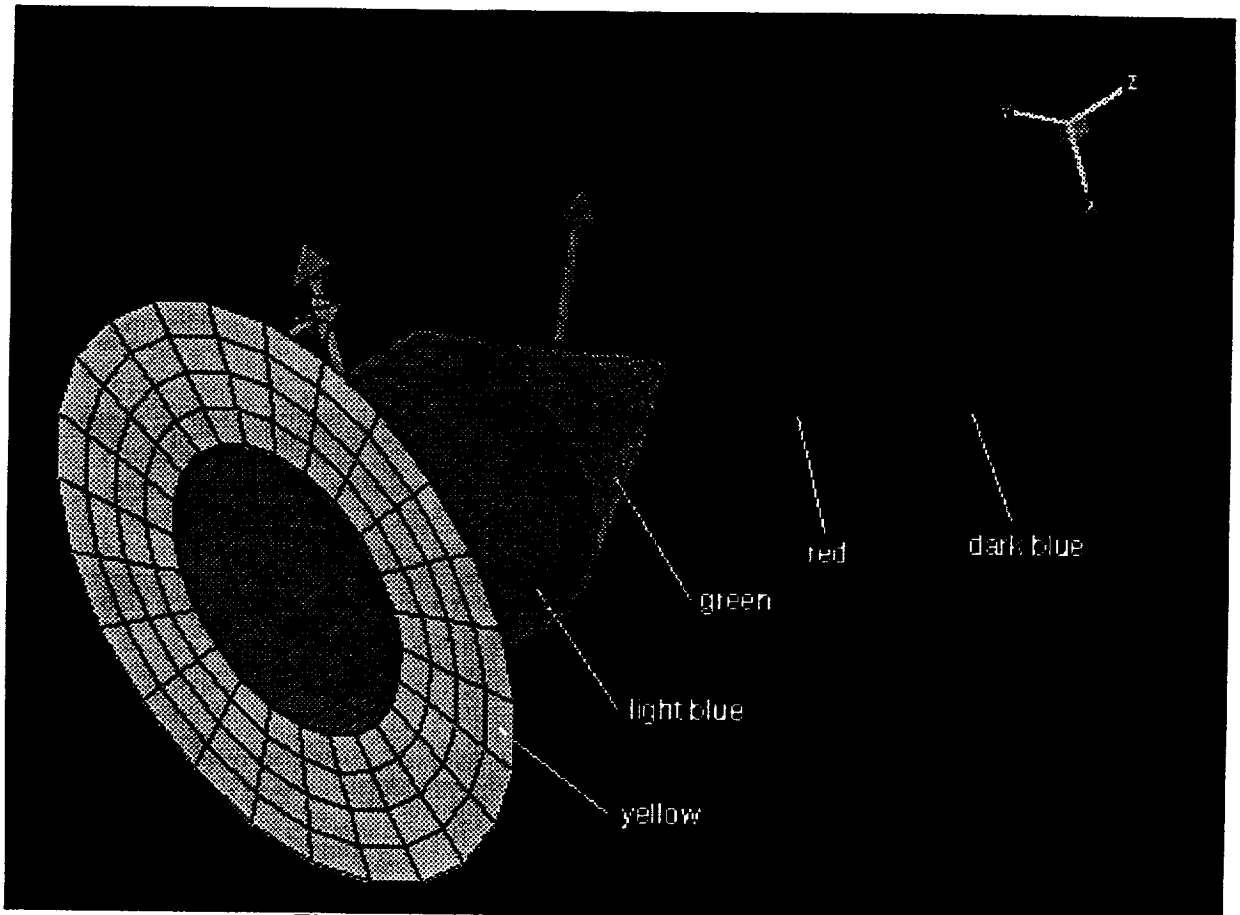

Figure A1. A Black and White Image of the Sample Geometry as Viewed Using MDDB and TECPLOT

```
CONE MATERIAL
    300.00      .3000     .6000     .0000     .1000     SP,DIF,RE,SR
 4     4    24 T T T
                .0000               .0000              1.0000
                .0000               .0000               .0000
               1.0000               .0000               .0000
               6.0000                                   .5000            360.0000
DISK
DISK MATERIAL
    300.00      .7000     .2500     .0500     .0000     SP,DIF,RE,SR
 5     6    24 T T T
                .0000               .0000              1.0000
                .0000               .0000             12.5000
               1.0000               .0000               .0000
               2.5000               .0010            179.9990            360.0000
SPHERE
SPHERE MATERIAL
    300.00      .0500     .9000     .0000     .0500     SP,DIF,RE,SR
 0     0     0 F F F    END OF GEOMETRY
F                     VECTIN
  0.00E+00  0.00E+00  0.00E+00      .0 0.000E+00  0.00E+00 RAM,TATM,ALFREF,AVDEN
      20        80     10  T  F  F  NTHETA,NPHI,MAXRAY,SHORTL,CHECK,INACT
  997531                 ISEED
```

A.3 Mission File

This is the file that is generated by FLUXAVG. This particular sample is for the first six months of the Space Station Freedom Mission.

Unix filename (generated by FLUXAVG): fluxavg.mission_sample26-Apr-93.1
Copied to PC as: mission.sam

```
#PROGRAM IDENTIFICATION
 MISSION FILE
 PROGRAM FLUXAVG
 ATOMIC OXYGEN EXPOSURE
 *  RELEASE VERSION 1.0                                   *
 *  COMPILED 26-Apr-93    08:26:43                        *
 DATE OF COMPUTATION:    26-Apr-93   08:47:51
#END PROGRAM IDENTIFICATION
#PROGRAM CONTROL FILE ECHO
 fluxavg.mission_sample
 fluxavg.in_sample
 This is a short run to test FLUXAVG.
 The start of the Space Station Freedom mission is run.
                 Described in Mission Profile Grumman
                 Memo P SH-314-M092-038
                 date Sept 8, 1991
 The second set of orbit elements is set to calculate fluxes and fluences
 at the orbit elements epoch date and at 7 and 14 days after.  The other
 sets of orbit elements calculate fluxes and fluences only on the
 epoch date.
 $
  0                                  IVEL FLAG FOR VELOCITY INFORMATION
 1995 11 30 13 55 21.80              MISSION START DATE (yyyy mm dd hh mm ss.ss)
 1996 02 03 03 51 45.3              MISSION END DATE
 solgeo.sample
 37                                  NAZEL NUMBER OF SURFACES
 SIDE 1                    0.         90.          PHI, THETA
 SIDE 2                    5.         90.
 SIDE 3                    10.        90.
 SIDE 4                    15.        90.
 SIDE 5                    20.        90.
 SIDE 6                    25.        90.
 SIDE 7                    30.        90.
 SIDE 8                    35.        90.
 SIDE 9                    40.        90.
 SIDE 10                   45.        90.
 SIDE 11                   50.        90.
 SIDE 12                   55.        90.
 SIDE 13                   60.        90.
 SIDE 14                   65.        90.
 SIDE 15                   70.        90.
 SIDE 16                   75.        90.
 SIDE 17                   80.        90.
 SIDE 18                   85.        90.
 SIDE 19                   90.        90.
 SIDE 20                   95.        90.
 SIDE 21                   100.       90.
 SIDE 22                   105.       90.
 SIDE 23                   110.       90.
 SIDE 24                   115.       90.
 SIDE 25                   120.       90.
 SIDE 26                   125.       90.
 SIDE 27                   130.       90.
 SIDE 28                   135.       90.
```

```
 SIDE 29                         140.       90.
 SIDE 30                         145.       90.
 SIDE 31                         150.       90.
 SIDE 32                         155.       90.
 SIDE 33                         160.       90.
 SIDE 34                         165.       90.
 SIDE 35                         170.       90.
 SIDE 36                         175.       90.
 SIDE 37                         180.       90.
 +Z +X
  0.0       0.0       0.0            roll,pitch,yaw
 orbinp.sample
#END PROGRAM CONTROL FILE ECHO
#MISSION FILE NAME
 fluxavg.mission_sample26-Apr-93.1
#END MISSION FILE NAME
#COMMENTARY
 This is a short run to test FLUXAVG.
 The start of the Space Station Freedom mission is run.
                 Described in Mission Profile Grumman
                 Memo P SH-314-M092-038
                 date Sept 8, 1991
 The second set of orbit elements is set to calculate fluxes and fluences
 at the orbit elements epoch date and at 7 and 14 days after.  The other
 sets of orbit elements calculate fluxes and fluences only on the
 epoch date.
 $
#END COMMENTARY
#SOLAR AND GEOMAGNETIC DATA ECHO
        2450051.500          REFERENCE JULIAN DATE
   YR  MO  DA  3 MO AV F10.7   WK AV F10.7          AP         RELATIVE DAY
 1995  11  30             92.            92.         17.               0.00
 1995  12   1             92.            92.         17.               1.00
 1995  12  31             92.            92.         17.              31.00
 1996   1   1             92.            92.         17.              32.00
 1996   1  31             91.            91.         17.              62.00
 1996   2  29             91.            91.         17.              91.00
#END SOLAR AND GEOMAGNETIC DATA ECHO
#SURFACE NORMAL DEFINITIONS
  37                        NAZEL
  NO.  SURFACE                          USER       USER      PROGRAM COORDINATES
                                    (DEGREES)  (DEGREES)  SURFACE NORMAL UNIT VECTOR
                                                                 X          Y          Z

    1  SIDE 1                           0.00      90.00    0.00000    0.00000    1.00000
    2  SIDE 2                           5.00      90.00    0.00000    0.08716    0.99619
    3  SIDE 3                          10.00      90.00    0.00000    0.17365    0.98481
    4  SIDE 4                          15.00      90.00    0.00000    0.25882    0.96593
    5  SIDE 5                          20.00      90.00    0.00000    0.34202    0.93969
    6  SIDE 6                          25.00      90.00    0.00000    0.42262    0.90631
    7  SIDE 7                          30.00      90.00    0.00000    0.50000    0.86603
    8  SIDE 8                          35.00      90.00    0.00000    0.57358    0.81915
    9  SIDE 9                          40.00      90.00    0.00000    0.64279    0.76604
   10  SIDE 10                         45.00      90.00    0.00000    0.70711    0.70711
   11  SIDE 11                         50.00      90.00    0.00000    0.76604    0.64279
   12  SIDE 12                         55.00      90.00    0.00000    0.81915    0.57358
   13  SIDE 13                         60.00      90.00    0.00000    0.86603    0.50000
   14  SIDE 14                         65.00      90.00    0.00000    0.90631    0.42262
   15  SIDE 15                         70.00      90.00    0.00000    0.93969    0.34202
   16  SIDE 16                         75.00      90.00    0.00000    0.96593    0.25882
   17  SIDE 17                         80.00      90.00    0.00000    0.98481    0.17365
   18  SIDE 18                         85.00      90.00    0.00000    0.99619    0.08716
   19  SIDE 19                         90.00      90.00    0.00000    1.00000    0.00000
   20  SIDE 20                         95.00      90.00    0.00000    0.99619   -0.08716
```

```
  21  SIDE 21                   100.00    90.00   0.00000   0.98481  -0.17365
  22  SIDE 22                   105.00    90.00   0.00000   0.96593  -0.25882
  23  SIDE 23                   110.00    90.00   0.00000   0.93969  -0.34202
  24  SIDE 24                   115.00    90.00   0.00000   0.90631  -0.42262
  25  SIDE 25                   120.00    90.00   0.00000   0.86603  -0.50000
  26  SIDE 26                   125.00    90.00   0.00000   0.81915  -0.57358
  27  SIDE 27                   130.00    90.00   0.00000   0.76604  -0.64279
  28  SIDE 28                   135.00    90.00   0.00000   0.70711  -0.70711
  29  SIDE 29                   140.00    90.00   0.00000   0.64279  -0.76604
  30  SIDE 30                   145.00    90.00   0.00000   0.57358  -0.81915
  31  SIDE 31                   150.00    90.00   0.00000   0.50000  -0.86603
  32  SIDE 32                   155.00    90.00   0.00000   0.42262  -0.90631
  33  SIDE 33                   160.00    90.00   0.00000   0.34202  -0.93969
  34  SIDE 34                   165.00    90.00   0.00000   0.25882  -0.96593
  35  SIDE 35                   170.00    90.00   0.00000   0.17365  -0.98481
  36  SIDE 36                   175.00    90.00   0.00000   0.08716  -0.99619
  37  SIDE 37                   180.00    90.00   0.00000   0.00000  -1.00000
#END SURFACE NORMAL DEFINITIONS
#ORBITAL PARAMETERS
        5         DATA SETS NORBE ON FILE
 orbinp.sample
        Julian Date   LOP Step day   # Steps Elem Type    C drag     Area km**2
    SC Mass kg     S M Axis km    Eccent  Incl degA node deg Arg P degM Anom deg
   ASAP step s   # Steps
     2450052.080113        7.00000        0         0  2.00000     1.0000E-06
    2.0000E+03      6716.970 0.0000000    28.500   342.200     0.000      0.000
        360.00      230
     2450053.286372        7.00000        2         0  2.00000     1.0000E-06
    2.0000E+03      6730.810 0.0000000    28.500   107.100     0.000      0.000
        360.00      230
     2450082.953700        7.00000        0         0  2.00000     1.0000E-06
    2.0000E+03      6726.420 0.0000000    28.500     2.300     0.000      0.000
        360.00      230
     2450083.775736        7.00000        0         0  2.00000     1.0000E-06
    2.0000E+03      6739.030 0.0000000    28.500   110.000     0.000      0.000
        360.00      230
     2450114.189101        7.00000        0         0  2.00000     1.0000E-06
    2.0000E+03      6733.620 0.0000000    28.500   137.800     0.000      0.000
        360.00      230
#END ORBITAL PARAMETERS
#FLUX AND FLUENCE MEAN ORBITAL PARAMETERS
         8        39          # OF INPUT DATES, TOTAL # OF SURFACES
    2450052.0801134  1995  11  30  13  55  21.80    JDATE AND DATE FLUENCE
          0.0000000           CUMULATIVE DAYS EXPOSURE
    2450053.0384468  1995  12   1  12  55  21.80    JDATE AND DATE ASAP END
    2450052.0801134  1995  11  30  13  55  21.80    JDATE AND DATE ASAP START
      231                    #POINTS IN ASAP RUN
  2.025E+08   3.070E+08   1.109E+08          AVG, MAX, MIN AO DEN (#/CM**3)
     883.05      1180.02      738.46          AVG, MAX, MIN TEMPERATURE (K)
     334.75      336.86      332.16          AVG, MAX, MIN ALTITUDE (KM)
     7.7109      7.7124      7.7099          AVG, MAX, MIN ABS SPEED (KM/S)
     7.2839      7.2873      7.2811          AVG, MAX, MIN REL SPEED (KM/S)
 NO. LOCATION                  THETA     PHI   AVERAGE AVERAGE FLUX    FLUENCE
                               (DEG)    (DEG) INCIDENCE  (#/CM**2/S)  (#/CM**2)
                                                 ANGLE
                                                 (DEG)
   1 SIDE 1                    90.00    0.00        1.2    1.47E+14   0.00E+00
   2 SIDE 2                    90.00    5.00        5.0    1.47E+14   0.00E+00
   3 SIDE 3                    90.00   10.00       10.0    1.45E+14   0.00E+00
   4 SIDE 4                    90.00   15.00       15.0    1.42E+14   0.00E+00
   5 SIDE 5                    90.00   20.00       20.0    1.38E+14   0.00E+00
   6 SIDE 6                    90.00   25.00       25.0    1.33E+14   0.00E+00
   7 SIDE 7                    90.00   30.00       30.0    1.27E+14   0.00E+00
   8 SIDE 8                    90.00   35.00       35.0    1.21E+14   0.00E+00
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9	SIDE 9	90.00	40.00	40.0	1.13E+14	0.00E+00
10	SIDE 10	90.00	45.00	45.0	1.04E+14	0.00E+00
11	SIDE 11	90.00	50.00	50.0	9.45E+13	0.00E+00
12	SIDE 12	90.00	55.00	55.0	8.42E+13	0.00E+00
13	SIDE 13	90.00	60.00	60.0	7.34E+13	0.00E+00
14	SIDE 14	90.00	65.00	65.0	6.19E+13	0.00E+00
15	SIDE 15	90.00	70.00	70.0	5.00E+13	0.00E+00
16	SIDE 16	90.00	75.00	75.0	3.78E+13	0.00E+00
17	SIDE 17	90.00	80.00	80.0	2.54E+13	0.00E+00
18	SIDE 18	90.00	85.00	85.0	1.40E+13	0.00E+00
19	SIDE 19	90.00	90.00	90.0	5.45E+12	0.00E+00
20	SIDE 20	90.00	95.00	95.0	1.31E+12	0.00E+00
21	SIDE 21	90.00	100.00	100.0	1.73E+11	0.00E+00
22	SIDE 22	90.00	105.00	105.0	1.22E+10	0.00E+00
23	SIDE 23	90.00	110.00	110.0	4.93E+08	0.00E+00
24	SIDE 24	90.00	115.00	115.0	1.29E+07	0.00E+00
25	SIDE 25	90.00	120.00	120.0	2.55E+05	0.00E+00
26	SIDE 26	90.00	125.00	125.0	4.29E+03	0.00E+00
27	SIDE 27	90.00	130.00	130.0	6.63E+01	0.00E+00
28	SIDE 28	90.00	135.00	135.0	1.02E+00	0.00E+00
29	SIDE 29	90.00	140.00	140.0	1.68E-02	0.00E+00
30	SIDE 30	90.00	145.00	145.0	3.28E-04	0.00E+00
31	SIDE 31	90.00	150.00	150.0	8.33E-06	0.00E+00
32	SIDE 32	90.00	155.00	155.0	3.02E-07	0.00E+00
33	SIDE 33	90.00	160.00	160.0	1.71E-08	0.00E+00
34	SIDE 34	90.00	165.00	165.0	1.64E-09	0.00E+00
35	SIDE 35	90.00	170.00	170.0	2.83E-10	0.00E+00
36	SIDE 36	90.00	175.00	175.0	9.26E-11	0.00E+00
37	SIDE 37	90.00	180.00	178.8	5.95E-11	0.00E+00
38	TRUE RAM			0.0	1.47E+14	0.00E+00
39	TRUE 90			90.0	5.48E+12	0.00E+00

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2450053.2863715  1995  12   1  18  52  22.50    JDATE AND DATE FLUENCE
      1.2062581          CUMULATIVE DAYS EXPOSURE
2450054.2447049  1995  12   2  17  52  22.50    JDATE AND DATE ASAP END
2450053.2863715  1995  12   1  18  52  22.50    JDATE AND DATE ASAP START
  231                    #POINTS IN ASAP RUN
1.542E+08    2.225E+08   8.785E+07       AVG, MAX, MIN AO DEN (#/CM**3)
   906.90      1151.59     738.59        AVG, MAX, MIN TEMPERATURE (K)
   348.60       350.74     345.94        AVG, MAX, MIN ALTITUDE (KM)
   7.7029       7.7045     7.7019        AVG, MAX, MIN ABS SPEED (KM/S)
   7.2750       7.2785     7.2722        AVG, MAX, MIN REL SPEED (KM/S)
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NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)
1	SIDE 1	90.00	0.00	1.2	1.12E+14	1.35E+19
2	SIDE 2	90.00	5.00	5.0	1.12E+14	1.35E+19
3	SIDE 3	90.00	10.00	10.0	1.10E+14	1.33E+19
4	SIDE 4	90.00	15.00	15.0	1.08E+14	1.31E+19
5	SIDE 5	90.00	20.00	20.0	1.05E+14	1.27E+19
6	SIDE 6	90.00	25.00	25.0	1.02E+14	1.22E+19
7	SIDE 7	90.00	30.00	30.0	9.70E+13	1.17E+19
8	SIDE 8	90.00	35.00	35.0	9.17E+13	1.11E+19
9	SIDE 9	90.00	40.00	40.0	8.57E+13	1.03E+19
10	SIDE 10	90.00	45.00	45.0	7.91E+13	9.54E+18
11	SIDE 11	90.00	50.00	50.0	7.19E+13	8.67E+18
12	SIDE 12	90.00	55.00	55.0	6.41E+13	7.73E+18
13	SIDE 13	90.00	60.00	60.0	5.58E+13	6.73E+18
14	SIDE 14	90.00	65.00	65.0	4.71E+13	5.68E+18
15	SIDE 15	90.00	70.00	70.0	3.81E+13	4.59E+18
16	SIDE 16	90.00	75.00	75.0	2.88E+13	3.47E+18

17	SIDE 17	90.00	80.00	80.0	1.94E+13	2.33E+18
18	SIDE 18	90.00	85.00	85.0	1.07E+13	1.28E+18
19	SIDE 19	90.00	90.00	90.0	4.22E+12	5.04E+17
20	SIDE 20	90.00	95.00	95.0	1.06E+12	1.23E+17
21	SIDE 21	90.00	100.00	100.0	1.55E+11	1.71E+16
22	SIDE 22	90.00	105.00	105.0	1.27E+10	1.30E+15
23	SIDE 23	90.00	110.00	110.0	6.03E+08	5.71E+13
24	SIDE 24	90.00	115.00	115.0	1.76E+07	1.59E+12
25	SIDE 25	90.00	120.00	120.0	3.45E+05	3.13E+10
26	SIDE 26	90.00	125.00	125.0	5.02E+03	4.85E+08
27	SIDE 27	90.00	130.00	130.0	6.03E+01	6.60E+06
28	SIDE 28	90.00	135.00	135.0	6.76E-01	8.82E+04
29	SIDE 29	90.00	140.00	140.0	8.02E-03	1.29E+03
30	SIDE 30	90.00	145.00	145.0	1.15E-04	2.31E+01
31	SIDE 31	90.00	150.00	150.0	2.27E-06	5.52E-01
32	SIDE 32	90.00	155.00	155.0	7.02E-08	1.94E-02
33	SIDE 33	90.00	160.00	160.0	3.79E-09	1.09E-03
34	SIDE 34	90.00	165.00	165.0	3.86E-10	1.05E-04
35	SIDE 35	90.00	170.00	170.0	7.82E-11	1.88E-05
36	SIDE 36	90.00	175.00	175.0	3.25E-11	6.52E-06
37	SIDE 37	90.00	180.00	178.8	2.78E-11	4.55E-06
38	TRUE RAM			0.0	1.12E+14	1.35E+19
39	TRUE 90			90.0	4.25E+12	5.07E+17

2450060.2863715 1995 12 8 18 52 22.50 JDATE AND DATE FLUENCE

8.2062581 CUMULATIVE DAYS EXPOSURE

2450061.2447049 1995 12 9 17 52 22.50 JDATE AND DATE ASAP END

2450060.2863715 1995 12 8 18 52 22.50 JDATE AND DATE ASAP START

231 #POINTS IN ASAP RUN

1.553E+08 2.567E+08 7.640E+07 AVG, MAX, MIN AO DEN (#/CM**3)

915.86 1182.83 744.44 AVG, MAX, MIN TEMPERATURE (K)

348.39 354.52 342.35 AVG, MAX, MIN ALTITUDE (KM)

7.7030 7.7089 7.6971 AVG, MAX, MIN ABS SPEED (KM/S)

7.2752 7.2827 7.2675 AVG, MAX, MIN REL SPEED (KM/S)

NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)
1	SIDE 1	90.00	0.00	1.2	1.13E+14	8.16E+19
2	SIDE 2	90.00	5.00	5.0	1.13E+14	8.13E+19
3	SIDE 3	90.00	10.00	10.0	1.11E+14	8.03E+19
4	SIDE 4	90.00	15.00	15.0	1.09E+14	7.88E+19
5	SIDE 5	90.00	20.00	20.0	1.06E+14	7.66E+19
6	SIDE 6	90.00	25.00	25.0	1.02E+14	7.38E+19
7	SIDE 7	90.00	30.00	30.0	9.76E+13	7.05E+19
8	SIDE 8	90.00	35.00	35.0	9.22E+13	6.67E+19
9	SIDE 9	90.00	40.00	40.0	8.62E+13	6.23E+19
10	SIDE 10	90.00	45.00	45.0	7.95E+13	5.75E+19
11	SIDE 11	90.00	50.00	50.0	7.22E+13	5.22E+19
12	SIDE 12	90.00	55.00	55.0	6.43E+13	4.66E+19
13	SIDE 13	90.00	60.00	60.0	5.60E+13	4.05E+19
14	SIDE 14	90.00	65.00	65.0	4.72E+13	3.42E+19
15	SIDE 15	90.00	70.00	70.0	3.81E+13	2.76E+19
16	SIDE 16	90.00	75.00	75.0	2.87E+13	2.08E+19
17	SIDE 17	90.00	80.00	80.0	1.92E+13	1.40E+19
18	SIDE 18	90.00	85.00	85.0	1.05E+13	7.68E+18
19	SIDE 19	90.00	90.00	90.0	4.12E+12	3.03E+18
20	SIDE 20	90.00	95.00	95.0	1.01E+12	7.49E+17
21	SIDE 21	90.00	100.00	100.0	1.39E+11	1.06E+17
22	SIDE 22	90.00	105.00	105.0	1.05E+10	8.33E+15
23	SIDE 23	90.00	110.00	110.0	4.56E+08	3.78E+14
24	SIDE 24	90.00	115.00	115.0	1.25E+07	1.07E+13

25	SIDE 25	90.00	120.00	120.0	2.41E+05	2.09E+11
26	SIDE 26	90.00	125.00	125.0	3.68E+03	3.12E+09
27	SIDE 27	90.00	130.00	130.0	4.92E+01	3.97E+07
28	SIDE 28	90.00	135.00	135.0	6.41E-01	4.87E+05
29	SIDE 29	90.00	140.00	140.0	9.20E-03	6.50E+03
30	SIDE 30	90.00	145.00	145.0	1.63E-04	1.07E+02
31	SIDE 31	90.00	150.00	150.0	4.02E-06	2.45E+00
32	SIDE 32	90.00	155.00	155.0	1.51E-07	8.64E-02
33	SIDE 33	90.00	160.00	160.0	9.48E-09	5.10E-03
34	SIDE 34	90.00	165.00	165.0	1.06E-09	5.43E-04
35	SIDE 35	90.00	170.00	170.0	2.24E-10	1.10E-04
36	SIDE 36	90.00	175.00	175.0	9.21E-11	4.42E-05
37	SIDE 37	90.00	180.00	178.8	7.55E-11	3.58E-05
38	TRUE RAM			0.0	1.13E+14	8.16E+19
39	TRUE 90			90.0	4.30E+12	3.09E+18

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2450067.2863715  1995  12  15  18  52  22.50     JDATE AND DATE FLUENCE
     15.2062581          CUMULATIVE DAYS EXPOSURE
2450068.2447049  1995  12  16  17  52  22.50     JDATE AND DATE ASAP END
2450067.2863715  1995  12  15  18  52  22.50     JDATE AND DATE ASAP START
  231                    #POINTS IN ASAP RUN
1.455E+08   2.393E+08   7.067E+07         AVG, MAX, MIN AO DEN (#/CM**3)
  887.51     1182.86      726.63          AVG, MAX, MIN TEMPERATURE (K)
  348.19      357.03      342.76          AVG, MAX, MIN ALTITUDE (KM)
  7.7031      7.7102      7.6945          AVG, MAX, MIN ABS SPEED (KM/S)
  7.2753      7.2818      7.2643          AVG, MAX, MIN REL SPEED (KM/S)
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NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)
1	SIDE 1	90.00	0.00	1.2	1.06E+14	1.48E+20
2	SIDE 2	90.00	5.00	5.0	1.05E+14	1.47E+20
3	SIDE 3	90.00	10.00	10.0	1.04E+14	1.45E+20
4	SIDE 4	90.00	15.00	15.0	1.02E+14	1.43E+20
5	SIDE 5	90.00	20.00	20.0	9.94E+13	1.39E+20
6	SIDE 6	90.00	25.00	25.0	9.58E+13	1.34E+20
7	SIDE 7	90.00	30.00	30.0	9.15E+13	1.28E+20
8	SIDE 8	90.00	35.00	35.0	8.65E+13	1.21E+20
9	SIDE 9	90.00	40.00	40.0	8.09E+13	1.13E+20
10	SIDE 10	90.00	45.00	45.0	7.46E+13	1.04E+20
11	SIDE 11	90.00	50.00	50.0	6.78E+13	9.45E+19
12	SIDE 12	90.00	55.00	55.0	6.04E+13	8.43E+19
13	SIDE 13	90.00	60.00	60.0	5.26E+13	7.34E+19
14	SIDE 14	90.00	65.00	65.0	4.44E+13	6.19E+19
15	SIDE 15	90.00	70.00	70.0	3.59E+13	5.00E+19
16	SIDE 16	90.00	75.00	75.0	2.71E+13	3.77E+19
17	SIDE 17	90.00	80.00	80.0	1.82E+13	2.53E+19
18	SIDE 18	90.00	85.00	85.0	9.99E+12	1.39E+19
19	SIDE 19	90.00	90.00	90.0	3.91E+12	5.45E+18
20	SIDE 20	90.00	95.00	95.0	9.45E+11	1.34E+18
21	SIDE 21	90.00	100.00	100.0	1.27E+11	1.87E+17
22	SIDE 22	90.00	105.00	105.0	9.30E+09	1.43E+16
23	SIDE 23	90.00	110.00	110.0	3.92E+08	6.34E+14
24	SIDE 24	90.00	115.00	115.0	1.08E+07	1.77E+13
25	SIDE 25	90.00	120.00	120.0	2.25E+05	3.49E+11
26	SIDE 26	90.00	125.00	125.0	3.89E+03	5.41E+09
27	SIDE 27	90.00	130.00	130.0	6.12E+01	7.31E+07
28	SIDE 28	90.00	135.00	135.0	9.49E-01	9.67E+05
29	SIDE 29	90.00	140.00	140.0	1.59E-02	1.41E+04
30	SIDE 30	90.00	145.00	145.0	3.15E-04	2.52E+02
31	SIDE 31	90.00	150.00	150.0	8.22E-06	6.15E+00
32	SIDE 32	90.00	155.00	155.0	3.09E-07	2.26E-01

33	SIDE 33	90.00	160.00	160.0	1.83E-08	1.35E-02
34	SIDE 34	90.00	165.00	165.0	1.85E-09	1.42E-03
35	SIDE 35	90.00	170.00	170.0	3.41E-10	2.81E-04
36	SIDE 36	90.00	175.00	175.0	1.19E-10	1.08E-04
37	SIDE 37	90.00	180.00	178.8	8.17E-11	8.33E-05
38	TRUE RAM			0.0	1.06E+14	1.48E+20
39	TRUE 90			90.0	3.95E+12	5.59E+18

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  2450082.9537002  1995  12  31  10  53  19.70     JDATE AND DATE FLUENCE
       30.8735868           CUMULATIVE DAYS EXPOSURE
  2450083.9120336  1996   1   1   9  53  19.70     JDATE AND DATE ASAP END
  2450082.9537002  1995  12  31  10  53  19.70     JDATE AND DATE ASAP START
    231                     #POINTS IN ASAP RUN
 1.658E+08    2.487E+08    8.914E+07         AVG, MAX, MIN AO DEN (#/CM**3)
    864.07      1173.86      732.69          AVG, MAX, MIN TEMPERATURE (K)
    344.21       346.36      341.50          AVG, MAX, MIN ALTITUDE (KM)
    7.7054       7.7070      7.7045          AVG, MAX, MIN ABS SPEED (KM/S)
    7.2778       7.2814      7.2750          AVG, MAX, MIN REL SPEED (KM/S)
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NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)
1	SIDE 1	90.00	0.00	1.2	1.21E+14	3.01E+20
2	SIDE 2	90.00	5.00	5.0	1.20E+14	3.00E+20
3	SIDE 3	90.00	10.00	10.0	1.19E+14	2.96E+20
4	SIDE 4	90.00	15.00	15.0	1.16E+14	2.91E+20
5	SIDE 5	90.00	20.00	20.0	1.13E+14	2.83E+20
6	SIDE 6	90.00	25.00	25.0	1.09E+14	2.72E+20
7	SIDE 7	90.00	30.00	30.0	1.04E+14	2.60E+20
8	SIDE 8	90.00	35.00	35.0	9.87E+13	2.46E+20
9	SIDE 9	90.00	40.00	40.0	9.23E+13	2.30E+20
10	SIDE 10	90.00	45.00	45.0	8.51E+13	2.12E+20
11	SIDE 11	90.00	50.00	50.0	7.74E+13	1.93E+20
12	SIDE 12	90.00	55.00	55.0	6.90E+13	1.72E+20
13	SIDE 13	90.00	60.00	60.0	6.01E+13	1.50E+20
14	SIDE 14	90.00	65.00	65.0	5.08E+13	1.26E+20
15	SIDE 15	90.00	70.00	70.0	4.10E+13	1.02E+20
16	SIDE 16	90.00	75.00	75.0	3.10E+13	7.70E+19
17	SIDE 17	90.00	80.00	80.0	2.09E+13	5.18E+19
18	SIDE 18	90.00	85.00	85.0	1.15E+13	2.84E+19
19	SIDE 19	90.00	90.00	90.0	4.46E+12	1.11E+19
20	SIDE 20	90.00	95.00	95.0	1.06E+12	2.70E+18
21	SIDE 21	90.00	100.00	100.0	1.38E+11	3.66E+17
22	SIDE 22	90.00	105.00	105.0	9.30E+09	2.69E+16
23	SIDE 23	90.00	110.00	110.0	3.41E+08	1.13E+15
24	SIDE 24	90.00	115.00	115.0	7.50E+06	3.01E+13
25	SIDE 25	90.00	120.00	120.0	1.16E+05	5.80E+11
26	SIDE 26	90.00	125.00	125.0	1.48E+03	9.04E+09
27	SIDE 27	90.00	130.00	130.0	1.81E+01	1.27E+08
28	SIDE 28	90.00	135.00	135.0	2.37E-01	1.77E+06
29	SIDE 29	90.00	140.00	140.0	3.65E-03	2.73E+04
30	SIDE 30	90.00	145.00	145.0	7.11E-05	5.13E+02
31	SIDE 31	90.00	150.00	150.0	1.88E-06	1.30E+01
32	SIDE 32	90.00	155.00	155.0	7.31E-08	4.84E-01
33	SIDE 33	90.00	160.00	160.0	4.50E-09	2.90E-02
34	SIDE 34	90.00	165.00	165.0	4.71E-10	3.00E-03
35	SIDE 35	90.00	170.00	170.0	8.92E-11	5.72E-04
36	SIDE 36	90.00	175.00	175.0	3.20E-11	2.10E-04
37	SIDE 37	90.00	180.00	178.8	2.24E-11	1.54E-04
38	TRUE RAM			0.0	1.21E+14	3.01E+20
39	TRUE 90			90.0	4.44E+12	1.13E+19

```
   2450083.7757361  1996   1   1   6  37   3.60     JDATE AND DATE FLUENCE
        31.6956227          CUMULATIVE DAYS EXPOSURE
   2450084.7340694  1996   1   2   5  37   3.60     JDATE AND DATE ASAP END
   2450083.7757361  1996   1   1   6  37   3.60     JDATE AND DATE ASAP START
    231                    #POINTS IN ASAP RUN
  1.183E+08   1.854E+08  5.769E+07        AVG, MAX, MIN AO DEN (#/CM**3)
     894.35     1147.51    747.15         AVG, MAX, MIN TEMPERATURE (K)
     356.83      358.96    354.18         AVG, MAX, MIN ALTITUDE (KM)
     7.6982      7.6997    7.6972         AVG, MAX, MIN ABS SPEED (KM/S)
     7.2698      7.2733    7.2670         AVG, MAX, MIN REL SPEED (KM/S)
```

NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)
1	SIDE 1	90.00	0.00	1.2	8.60E+13	3.08E+20
2	SIDE 2	90.00	5.00	5.0	8.56E+13	3.07E+20
3	SIDE 3	90.00	10.00	10.0	8.46E+13	3.04E+20
4	SIDE 4	90.00	15.00	15.0	8.29E+13	2.98E+20
5	SIDE 5	90.00	20.00	20.0	8.06E+13	2.89E+20
6	SIDE 6	90.00	25.00	25.0	7.77E+13	2.79E+20
7	SIDE 7	90.00	30.00	30.0	7.43E+13	2.67E+20
8	SIDE 8	90.00	35.00	35.0	7.02E+13	2.52E+20
9	SIDE 9	90.00	40.00	40.0	6.56E+13	2.36E+20
10	SIDE 10	90.00	45.00	45.0	6.05E+13	2.17E+20
11	SIDE 11	90.00	50.00	50.0	5.50E+13	1.97E+20
12	SIDE 12	90.00	55.00	55.0	4.90E+13	1.76E+20
13	SIDE 13	90.00	60.00	60.0	4.26E+13	1.53E+20
14	SIDE 14	90.00	65.00	65.0	3.60E+13	1.29E+20
15	SIDE 15	90.00	70.00	70.0	2.90E+13	1.05E+20
16	SIDE 16	90.00	75.00	75.0	2.19E+13	7.89E+19
17	SIDE 17	90.00	80.00	80.0	1.47E+13	5.30E+19
18	SIDE 18	90.00	85.00	85.0	8.02E+12	2.91E+19
19	SIDE 19	90.00	90.00	90.0	3.13E+12	1.14E+19
20	SIDE 20	90.00	95.00	95.0	7.59E+11	2.76E+18
21	SIDE 21	90.00	100.00	100.0	1.04E+11	3.74E+17
22	SIDE 22	90.00	105.00	105.0	7.83E+09	2.75E+16
23	SIDE 23	90.00	110.00	110.0	3.34E+08	1.15E+15
24	SIDE 24	90.00	115.00	115.0	8.83E+06	3.07E+13
25	SIDE 25	90.00	120.00	120.0	1.62E+05	5.90E+11
26	SIDE 26	90.00	125.00	125.0	2.29E+03	9.18E+09
27	SIDE 27	90.00	130.00	130.0	2.77E+01	1.28E+08
28	SIDE 28	90.00	135.00	135.0	3.22E-01	1.79E+06
29	SIDE 29	90.00	140.00	140.0	4.01E-03	2.76E+04
30	SIDE 30	90.00	145.00	145.0	6.11E-05	5.18E+02
31	SIDE 31	90.00	150.00	150.0	1.29E-06	1.31E+01
32	SIDE 32	90.00	155.00	155.0	4.21E-08	4.88E-01
33	SIDE 33	90.00	160.00	160.0	2.37E-09	2.92E-02
34	SIDE 34	90.00	165.00	165.0	2.48E-10	3.02E-03
35	SIDE 35	90.00	170.00	170.0	5.07E-11	5.77E-04
36	SIDE 36	90.00	175.00	175.0	2.10E-11	2.12E-04
37	SIDE 37	90.00	180.00	178.8	1.79E-11	1.55E-04
38	TRUE RAM			0.0	8.60E+13	3.09E+20
39	TRUE 90			90.0	3.23E+12	1.15E+19

```
   2450114.1891007  1996   1  31  16  32  18.30     JDATE AND DATE FLUENCE
        62.1089873          CUMULATIVE DAYS EXPOSURE
   2450115.1474340  1996   2   1  15  32  18.30     JDATE AND DATE ASAP END
   2450114.1891007  1996   1  31  16  32  18.30     JDATE AND DATE ASAP START
    231                    #POINTS IN ASAP RUN
  1.209E+08   1.926E+08  6.344E+07        AVG, MAX, MIN AO DEN (#/CM**3)
```

AVG	MAX	MIN	
883.73	1129.42	729.33	AVG, MAX, MIN TEMPERATURE (K)
351.42	353.55	348.79	AVG, MAX, MIN ALTITUDE (KM)
7.7013	7.7028	7.7003	AVG, MAX, MIN ABS SPEED (KM/S)
7.2732	7.2767	7.2704	AVG, MAX, MIN REL SPEED (KM/S)

NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)
1	SIDE 1	90.00	0.00	1.2	8.79E+13	5.37E+20
2	SIDE 2	90.00	5.00	5.0	8.76E+13	5.35E+20
3	SIDE 3	90.00	10.00	10.0	8.65E+13	5.28E+20
4	SIDE 4	90.00	15.00	15.0	8.48E+13	5.18E+20
5	SIDE 5	90.00	20.00	20.0	8.25E+13	5.04E+20
6	SIDE 6	90.00	25.00	25.0	7.95E+13	4.86E+20
7	SIDE 7	90.00	30.00	30.0	7.59E+13	4.64E+20
8	SIDE 8	90.00	35.00	35.0	7.18E+13	4.39E+20
9	SIDE 9	90.00	40.00	40.0	6.71E+13	4.10E+20
10	SIDE 10	90.00	45.00	45.0	6.19E+13	3.78E+20
11	SIDE 11	90.00	50.00	50.0	5.62E+13	3.44E+20
12	SIDE 12	90.00	55.00	55.0	5.01E+13	3.06E+20
13	SIDE 13	90.00	60.00	60.0	4.36E+13	2.67E+20
14	SIDE 14	90.00	65.00	65.0	3.68E+13	2.25E+20
15	SIDE 15	90.00	70.00	70.0	2.97E+13	1.82E+20
16	SIDE 16	90.00	75.00	75.0	2.24E+13	1.37E+20
17	SIDE 17	90.00	80.00	80.0	1.50E+13	9.21E+19
18	SIDE 18	90.00	85.00	85.0	8.18E+12	5.04E+19
19	SIDE 19	90.00	90.00	90.0	3.17E+12	1.97E+19
20	SIDE 20	90.00	95.00	95.0	7.59E+11	4.76E+18
21	SIDE 21	90.00	100.00	100.0	1.01E+11	6.44E+17
22	SIDE 22	90.00	105.00	105.0	7.25E+09	4.73E+16
23	SIDE 23	90.00	110.00	110.0	2.90E+08	1.97E+15
24	SIDE 24	90.00	115.00	115.0	7.17E+06	5.17E+13
25	SIDE 25	90.00	120.00	120.0	1.24E+05	9.65E+11
26	SIDE 26	90.00	125.00	125.0	1.68E+03	1.44E+10
27	SIDE 27	90.00	130.00	130.0	1.99E+01	1.91E+08
28	SIDE 28	90.00	135.00	135.0	2.28E-01	2.51E+06
29	SIDE 29	90.00	140.00	140.0	2.84E-03	3.66E+04
30	SIDE 30	90.00	145.00	145.0	4.35E-05	6.55E+02
31	SIDE 31	90.00	150.00	150.0	9.15E-07	1.60E+01
32	SIDE 32	90.00	155.00	155.0	2.96E-08	5.83E-01
33	SIDE 33	90.00	160.00	160.0	1.62E-09	3.45E-02
34	SIDE 34	90.00	165.00	165.0	1.60E-10	3.56E-03
35	SIDE 35	90.00	170.00	170.0	3.08E-11	6.84E-04
36	SIDE 36	90.00	175.00	175.0	1.19E-11	2.55E-04
37	SIDE 37	90.00	180.00	178.8	9.38E-12	1.91E-04
38	TRUE RAM			0.0	8.79E+13	5.37E+20
39	TRUE 90			90.0	3.27E+12	2.01E+19

2450116.6609410 1996 2 3 3 51 45.30 JDATE AND DATE FLUENCE

64.5808275 CUMULATIVE DAYS EXPOSURE

2450116.6609410 1996 2 3 3 51 45.30 JDATE AND DATE ASAP END

2450115.7026076 1996 2 2 4 51 45.30 JDATE AND DATE ASAP START

231 #POINTS IN ASAP RUN

AVG	MAX	MIN	
1.237E+08	1.992E+08	6.099E+07	AVG, MAX, MIN AO DEN (#/CM**3)
888.18	1131.61	718.66	AVG, MAX, MIN TEMPERATURE (K)
351.37	353.99	347.77	AVG, MAX, MIN ALTITUDE (KM)
7.7013	7.7040	7.6995	AVG, MAX, MIN ABS SPEED (KM/S)
7.2733	7.2779	7.2699	AVG, MAX, MIN REL SPEED (KM/S)

NO.	LOCATION	THETA (DEG)	PHI (DEG)	AVERAGE INCIDENCE ANGLE (DEG)	AVERAGE FLUX (#/CM**2/S)	FLUENCE (#/CM**2)

```
 1 SIDE 1        90.00    0.00    1.2   8.99E+13  5.56E+20
 2 SIDE 2        90.00    5.00    5.0   8.96E+13  5.54E+20
 3 SIDE 3        90.00   10.00   10.0   8.85E+13  5.47E+20
 4 SIDE 4        90.00   15.00   15.0   8.68E+13  5.36E+20
 5 SIDE 5        90.00   20.00   20.0   8.44E+13  5.22E+20
 6 SIDE 6        90.00   25.00   25.0   8.13E+13  5.03E+20
 7 SIDE 7        90.00   30.00   30.0   7.77E+13  4.80E+20
 8 SIDE 8        90.00   35.00   35.0   7.34E+13  4.54E+20
 9 SIDE 9        90.00   40.00   40.0   6.86E+13  4.24E+20
10 SIDE 10       90.00   45.00   45.0   6.33E+13  3.92E+20
11 SIDE 11       90.00   50.00   50.0   5.75E+13  3.56E+20
12 SIDE 12       90.00   55.00   55.0   5.12E+13  3.17E+20
13 SIDE 13       90.00   60.00   60.0   4.46E+13  2.76E+20
14 SIDE 14       90.00   65.00   65.0   3.76E+13  2.33E+20
15 SIDE 15       90.00   70.00   70.0   3.03E+13  1.88E+20
16 SIDE 16       90.00   75.00   75.0   2.28E+13  1.42E+20
17 SIDE 17       90.00   80.00   80.0   1.53E+13  9.53E+19
18 SIDE 18       90.00   85.00   85.0   8.34E+12  5.21E+19
19 SIDE 19       90.00   90.00   90.0   3.23E+12  2.04E+19
20 SIDE 20       90.00   95.00   95.0   7.72E+11  4.92E+18
21 SIDE 21       90.00  100.00  100.0   1.03E+11  6.66E+17
22 SIDE 22       90.00  105.00  105.0   7.32E+09  4.89E+16
23 SIDE 23       90.00  110.00  110.0   2.92E+08  2.04E+15
24 SIDE 24       90.00  115.00  115.0   7.16E+06  5.33E+13
25 SIDE 25       90.00  120.00  120.0   1.23E+05  9.92E+11
26 SIDE 26       90.00  125.00  125.0   1.66E+03  1.47E+10
27 SIDE 27       90.00  130.00  130.0   1.94E+01  1.95E+08
28 SIDE 28       90.00  135.00  135.0   2.20E-01  2.56E+06
29 SIDE 29       90.00  140.00  140.0   2.69E-03  3.72E+04
30 SIDE 30       90.00  145.00  145.0   4.03E-05  6.64E+02
31 SIDE 31       90.00  150.00  150.0   8.33E-07  1.62E+01
32 SIDE 32       90.00  155.00  155.0   2.67E-08  5.89E-01
33 SIDE 33       90.00  160.00  160.0   1.46E-09  3.48E-02
34 SIDE 34       90.00  165.00  165.0   1.47E-10  3.59E-03
35 SIDE 35       90.00  170.00  170.0   2.89E-11  6.90E-04
36 SIDE 36       90.00  175.00  175.0   1.15E-11  2.58E-04
37 SIDE 37       90.00  180.00  178.8   9.39E-12  1.93E-04
38 TRUE RAM                        0.0   9.00E+13  5.56E+20
39 TRUE 90                        90.0   3.36E+12  2.08E+19


#END FLUX AND FLUENCE MEAN ORBITAL PARAMETERS
```

A.4 Input File Generated by AVESHAD

This is the file generated by AVESHAD using the files shown in sections A.2 and A.3 as input. The event is chosen to be the first month of Space Station Freedom orbit.

File on PC: sample1.shd
to Convex: microenv/shadow.in_sample

```
Sample geometry flown for the first month of Space Station Freedom orbit.
EVENT START DATE: 1995   11   30   13   55   21.79
EVENT END DATE:   1995   12   30   13   55   21.79
 fluxavg.mission_sample26-Apr-93.1
SHADOWV2 sample file
 1    5    5 T T T
          -4.0000           -4.0000          15.0000
          -4.0000            4.0000          15.0000
           4.0000            4.0000          15.0000
                                              1.0000
PLANE
```

```
PLANE MATERIAL
    300.00     0.5000     0.5000     0.0000     0.0000     SP,DIF,RE,SR
 2     5    24 T T T
               0.0000                0.0000               1.0000
               0.0000                0.0000               0.0000
               1.0000                0.0000               0.0000
               3.0000                1.6667                                  360.0000
CYLINDER
CYLINDER MATERIAL
    300.00     0.2500     0.7000     0.0500     0.0000     SP,DIF,RE,SR
 3     6    24 T T T
               0.0000                0.0000               1.0000
               0.0000                0.0000               5.0000
               1.0000                0.0000               0.0000
               3.0000                1.6667               0.0000             360.0000
CONE                                                                         5
CONE MATERIAL
    300.00     0.3000     0.6000     0.0000     0.1000     SP,DIF,RE,SR
 4     4    24 T T T
               0.0000                0.0000               1.0000
               0.0000                0.0000               0.0000
               1.0000                0.0000               0.0000
               6.0000                                     0.5000             360.0000
DISK
DISK MATERIAL
    300.00     0.7000     0.2500     0.0500     0.0000     SP,DIF,RE,SR
 5     6    24 T T T
               0.0000                0.0000               1.0000
               0.0000                0.0000              12.5000
               1.0000                0.0000               0.0000
               2.5000                0.0000             180.0000             360.0000
SPHERE
SPHERE MATERIAL
    300.00     0.0500     0.9000     0.0000     0.0500     SP,DIF,RE,SR
 0     0     0 F F F     END OF GEOMETRY
F                      VECTIN
 7.276e+05  00.00  000.0  902.46  00.0  1.551e+08       RAM, TATM, ALFREF, AVDEN
      20        80        10   T  F  T    NTHETA,NPHI,MAXRAY,SHORTL,CHECK,INACT
  997531                       ISEED
```

A.5 Output File

This is the file that is generated by SHADOW as standard output, which is generally redirected to a file.

Convex file: microenv/shadow.out_sample

```
 PROGRAM SHADOW - ATOMIC OXYGEN MICROENVIRONMENT CODE

 DATE : 22-Feb-95    TIME : 08:32:42


 ECHO OF INPUT DECK

 Sample geometry flown for the first month of Space Station Freedom orbit.
 EVENT START DATE: 1995    11    30    13    55    21.79
 EVENT END DATE:   1995    12    30    13    55    21.79
  fluxavg.mission_sample26-Apr-93.1
 SHADOWV2 sample file
  1     5     5 T T T
               -4.0000                -4.0000               15.0000
```

```
              -4.0000             4.0000            15.0000
               4.0000             4.0000            15.0000
                                                     1.0000
PLANE
PLANE MATERIAL
    300.00    0.5000    0.5000    0.0000    0.0000    SP,DIF,RE,SR
 2    5   24 T T T
              0.0000              0.0000             1.0000
              0.0000              0.0000             0.0000
              1.0000              0.0000             0.0000
              3.0000              1.6667                              360.0000
CYLINDER
CYLINDER MATERIAL
    300.00    0.2500    0.7000    0.0500    0.0000    SP,DIF,RE,SR
 3    6   24 T T T
              0.0000              0.0000             1.0000
              0.0000              0.0000             5.0000
              1.0000              0.0000             0.0000
              3.0000              1.6667             0.0000           360.0000
CONE                                                                  5
CONE MATERIAL
    300.00    0.3000    0.6000    0.0000    0.1000    SP,DIF,RE,SR
 4    4   24 T T T
              0.0000              0.0000             1.0000
              0.0000              0.0000             0.0000
              1.0000              0.0000             0.0000
              6.0000                                 0.5000           360.0000
DISK
DISK MATERIAL
    300.00    0.7000    0.2500    0.0500    0.0000    SP,DIF,RE,SR
 5    6   24 T T T
              0.0000              0.0000             1.0000
              0.0000              0.0000            12.5000
              1.0000              0.0000             0.0000
              2.5000              0.0000           180.0000           360.0000
SPHERE
SPHERE MATERIAL
    300.00    0.0500    0.9000    0.0000    0.0500    SP,DIF,RE,SR
 0    0    0 F F F    END OF GEOMETRY
F                VECTIN
 7.276e+05  00.00  000.0  902.46  00.0  1.551e+08       RAM, TATM, ALFREF, AVD
     20       80       10  T  F  T    NTHETA,NPHI,MAXRAY,SHORTL,CHECK,INACT
  997531                    ISEED
```

```
Sample geometry flown for the first month of Space Station Freedom orbit.
EVENT START DATE: 1995   11   30   13   55   21.79
EVENT END DATE:   1995   12   30   13   55   21.79
 fluxavg.mission_sample26-Apr-93.1
a new file
OPRIMARY SURFACE     1          PLANE
 COORDINATES OF CORNERS (X,Y,Z)
 POINT P1      -4.00000000     -4.00000000     15.00000000
 POINT P2      -4.00000000      4.00000000     15.00000000
 POINT P3       4.00000000      4.00000000     15.00000000
 POINT P4       4.00000000     -4.00000000     15.00000000
 LENGTH RATIO  1.000000

 SURFACE PROPERTIES
    PLANE MATERIAL
```

```
     SURFACE TEMPERATURE (K)          300.0
     SPECULAR REFLECTIVITY              0.500
     DIFFUSE REFLECTIVITY               0.500
     RECOMBINATION EFFICIENCY           0.000
     SURFACE REACTIVITY                 0.000
0PRIMARY SURFACE    2          CYLINDER
CIRCULAR CONE SEGMENT
 COORDINATES (X,Y,Z) OF AXIS VECTOR E CENTER A OF MAXIMUM RADIUS CIRCLE , AND REFERENCE POINT
PR
 VECTOR E       0.00000000       0.00000000       1.00000000
 POINT A        0.00000000       0.00000000       0.00000000
 POINT PR       1.00000000       0.00000000       0.00000000
 MAXIMUM RADIUS R =         3.00000000
 RATIO H OF AXIS LENGTH TO RADIUS R =  1.66670000
 RADIUS RATIO G = 1.00000000
 SECTOR AZIMUTH UPPER LIMIT THETAM = 360.0000  DEGREES

 SURFACE PROPERTIES
     CYLINDER MATERIAL
     SURFACE TEMPERATURE (K)          300.0
     SPECULAR REFLECTIVITY              0.250
     DIFFUSE REFLECTIVITY               0.700
     RECOMBINATION EFFICIENCY           0.050
     SURFACE REACTIVITY                 0.000
0PRIMARY SURFACE    3          CONE
CIRCULAR CONE SEGMENT
 COORDINATES (X,Y,Z) OF AXIS VECTOR E CENTER A OF MAXIMUM RADIUS CIRCLE , AND REFERENCE POINT
PR
 VECTOR E       0.00000000       0.00000000       1.00000000
 POINT A        0.00000000       0.00000000       5.00000000
 POINT PR       1.00000000       0.00000000       0.00000000
 MAXIMUM RADIUS R =         3.00000000
 RATIO H OF AXIS LENGTH TO RADIUS R =  1.66670000
 RADIUS RATIO G = 0.00000000
 SECTOR AZIMUTH UPPER LIMIT THETAM = 360.0000  DEGREES

 SURFACE PROPERTIES
     CONE MATERIAL
     SURFACE TEMPERATURE (K)          300.0
     SPECULAR REFLECTIVITY              0.300
     DIFFUSE REFLECTIVITY               0.600
     RECOMBINATION EFFICIENCY           0.000
     SURFACE REACTIVITY                 0.100
0PRIMARY SURFACE    4          DISK                                                      DISC
SECTION
 COORDINATES (X,Y,Z) OF AXIS VECTOR E , CENTER A , AND REFERENCE POINT PR
 VECTOR E   0.00000E+00   0.00000E+00   0.10000E+01
 POINT A    0.00000E+00   0.00000E+00   0.00000E+00
 POINT PR   0.10000E+01   0.00000E+00   0.00000E+00
 OUTER RADIUS R =         6.00000000
 RATIO OF INNER TO OUTER RADIUS G = 0.50000000
 NOZ SURFACE AZIMUTH UPPER LIMIT THETAM= 360.0000  DEGREES

 SURFACE PROPERTIES
     DISK MATERIAL
     SURFACE TEMPERATURE (K)          300.0
     SPECULAR REFLECTIVITY              0.700
     DIFFUSE REFLECTIVITY               0.250
     RECOMBINATION EFFICIENCY           0.050
     SURFACE REACTIVITY                 0.000
0PRIMARY SURFACE    5          SPHERE                                                    SPHERE
SEGMENT
 COORDINATES (X,Y,Z) OF AXIS VECTOR E , CENTER A , AND REFERENCE POINT PR
 VECTOR E       0.00000000       0.00000000       1.00000000
```

```
 POINT A         0.00000000       0.00000000       12.50000000
 POINT PR        1.00000000       0.00000000        0.00000000
 RADIUS R=          2.50000000
 ANGLES IN DEGREES          PHI1=  0.00     PHI2=180.00     THETAM=360.00

 SURFACE PROPERTIES
     SPHERE MATERIAL
     SURFACE TEMPERATURE (K)        300.0
     SPECULAR REFLECTIVITY            0.050
     DIFFUSE REFLECTIVITY             0.900
     RECOMBINATION EFFICIENCY         0.000
     SURFACE REACTIVITY               0.050
OTOTAL PRIMARY SURFACES          5
 TOTAL NODAL SURFACES          529

 CPU TIME AFTER LEAVING RAYG1    0.0643 S
 TOTAL AREA OF OBJECT NODES IS       376.56872
ORAM VECTOR COMPONENTS
     X            0.00      Y            0.00      Z       727600.00
     MAGNITUDE      727600.00 CM/S
     DIRECTION:  ELEVATION            0.000 DEGREES
                 AZIMUTH              0.000 DEGREES
OATMOSPHERIC TEMPERATURE       902.5 K
 MEAN ATOMIC OXYGEN VELOCITY        1092.8 M/S
 AVERAGE ATOMIC OXYGEN DENSITY     1.55E+08 /CM**3
OANGLE BETWEEN REFERENCE SURFACE NORMAL AND RAM DIRECTION       0.00 DEGREES
0          UPPER HALF PLANE SPACE IS DIVIDED AS FOLLOWS:


      20 EQUAL INCREMENTS OF THETA (ZENITH) =     4.500  DEGREES STARTING AT     0.000
DEGREES
      80 EQUAL INCREMENTS OF PHI (AZIMUTH)  =     4.500  DEGREES STARTING AT     0.000
DEGREES
 ORDERING IS ALL PHI INCREMENTS ARE GENERATED BEFORE THETA IS INCREMENTED
 RAY DIRECTIONS ARE CENTERED IN THE THETA, PHI BINS

 Iseed used is:      997531
OAFTER CONVERGENCE IN GENDFDW, INTEGRAL OF VELOCITY DISTRIBUTION =    1.00000000000000
 CONVERGENCE WAS COMPLETED IN          943 STEPS
 SPEED AT CONVERGENCE =      9.4250 C =  1029961.8 CM/S
  CBAR =    109279.8 CM/S
1T,VR,DELC,C      902.5  7.2760E+05  1.0928E+03  1.0300E+06
     I  ALPHA(I)      DFDW(I)

     0        0.0  1.3400E+07
     1        1.0  1.3121E+07
     2        2.0  1.2451E+07
     3        3.0  1.1417E+07
     4        4.0  1.0081E+07
     5        5.0  8.6278E+06
     6        6.0  7.0946E+06
     7        7.0  5.6672E+06
     8        8.0  4.3661E+06
     9        9.0  3.2480E+06
    10       10.0  2.3392E+06
    11       11.0  1.6369E+06
    12       12.0  1.0961E+06
    13       13.0  7.1860E+05
    14       14.0  4.5424E+05
    15       15.0  2.7731E+05
    16       16.0  1.6517E+05
    17       17.0  9.5625E+04
    18       18.0  5.3306E+04
    19       19.0  2.9166E+04
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     20       20.0  1.5377E+04
     21       21.0  7.9135E+03
     22       22.0  3.9848E+03
     23       23.0  1.9374E+03
     24       24.0  9.1896E+02
     25       25.0  4.3157E+02
     26       26.0  1.9410E+02
     27       27.0  8.7099E+01
     28       28.0  3.7921E+01
     29       29.0  1.6015E+01
     30       30.0  6.7435E+00
     31       31.0  2.7615E+00
     32       32.0  1.1165E+00
     33       33.0  4.4310E-01
     34       34.0  1.7129E-01
     35       35.0  6.7338E-02
     36       36.0  2.5163E-02
     37       37.0  9.5404E-03
     38       38.0  3.5714E-03
     39       39.0  1.3081E-03
     40       40.0  4.6908E-04
     41       41.0  1.7182E-04
     42       42.0  6.2459E-05
     43       43.0  2.2226E-05
     44       44.0  7.9177E-06
     45       45.0  2.7948E-06
     46       46.0  1.0005E-06
     47       47.0  3.5518E-07
     48       48.0  1.2594E-07
     49       49.0  4.3981E-08
1T,VR,DELC,C      902.5  7.2760E+05   1.0928E+03   1.0300E+06
      I  ALPHA(I)      DFDW(I)

     50       50.0  1.6040E-08
     51       51.0  5.6718E-09
     52       52.0  2.0473E-09
     53       53.0  7.3925E-10
     54       54.0  2.7044E-10
     55       55.0  9.9751E-11
     56       56.0  3.6095E-11
     57       57.0  1.3979E-11
     58       58.0  5.0899E-12
     59       59.0  1.9772E-12
     60       60.0  7.7054E-13
     61       61.0  2.9556E-13
     62       62.0  1.2490E-13
     63       63.0  4.8345E-14
     64       64.0  2.0514E-14
     65       65.0  8.6268E-15
     66       66.0  3.6834E-15
     67       67.0  1.5535E-15
     68       68.0  7.1887E-16
     69       69.0  3.2200E-16
     70       70.0  1.4744E-16
     71       71.0  6.8357E-17
     72       72.0  3.4116E-17
     73       73.0  1.6716E-17
     74       74.0  8.5420E-18
     75       75.0  4.2939E-18
     76       76.0  2.2474E-18
     77       77.0  1.2184E-18
     78       78.0  6.9678E-19
     79       79.0  3.8343E-19
     80       80.0  2.1748E-19
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81	81.0	1.2792E-19
82	82.0	7.6043E-20
83	83.0	4.8147E-20
84	84.0	2.9323E-20
85	85.0	1.8887E-20
86	86.0	1.2816E-20
87	87.0	7.9759E-21
88	88.0	5.6367E-21
89	89.0	3.7483E-21
90	90.0	2.6832E-21
91	91.0	1.9284E-21
92	92.0	1.3547E-21
93	93.0	1.0147E-21
94	94.0	7.2357E-22
95	95.0	5.7495E-22
96	96.0	4.2558E-22
97	97.0	3.4541E-22
98	98.0	2.4798E-22
99	99.0	1.9800E-22

1T,VR,DELC,C   902.5 7.2760E+05 1.0928E+03 1.0300E+06

I	ALPHA(I)	DFDW(I)
100	100.0	1.6859E-22
101	101.0	1.4053E-22
102	102.0	9.4674E-23
103	103.0	8.0091E-23
104	104.0	7.3458E-23
105	105.0	5.9105E-23
106	106.0	6.0613E-23
107	107.0	3.1230E-23
108	108.0	3.9646E-23
109	109.0	3.2268E-23
110	110.0	2.4400E-23
111	111.0	2.2115E-23
112	112.0	2.0324E-23
113	113.0	1.8583E-23
114	114.0	1.3563E-23
115	115.0	1.3184E-23
116	116.0	1.1310E-23
117	117.0	1.0326E-23
118	118.0	1.0509E-23
119	119.0	7.0977E-24
120	120.0	7.3804E-24
121	121.0	7.7838E-24
122	122.0	3.8419E-24
123	123.0	7.9413E-24
124	124.0	4.1586E-24
125	125.0	4.1827E-24
126	126.0	4.4183E-24
127	127.0	3.9337E-24
128	128.0	3.8311E-24
129	129.0	2.5286E-24
130	130.0	3.6816E-24
131	131.0	2.5854E-24
132	132.0	2.9941E-24
133	133.0	3.3726E-24
134	134.0	6.1095E-25
135	135.0	2.4519E-24
136	136.0	2.1895E-24
137	137.0	1.9671E-24
138	138.0	1.8301E-24
139	139.0	1.3801E-24
140	140.0	1.5770E-24
141	141.0	1.7190E-24

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   142      142.0  1.0661E-24
   143      143.0  1.6785E-24
   144      144.0  9.9344E-25
   145      145.0  1.5877E-24
   146      146.0  9.2160E-25
   147      147.0  9.5622E-25
   148      148.0  1.3405E-24
   149      149.0  8.7183E-25
1T,VR,DELC,C      902.5  7.2760E+05  1.0928E+03  1.0300E+06
     I  ALPHA(I)      DFDW(I)

   150      150.0  1.2289E-24
   151      151.0  1.1219E-24
   152      152.0  5.7001E-25
   153      153.0  1.2300E-24
   154      154.0  5.5691E-25
   155      155.0  1.0462E-24
   156      156.0  6.5195E-25
   157      157.0  9.4023E-25
   158      158.0  7.9019E-25
   159      159.0  7.7605E-25
   160      160.0  4.8114E-25
   161      161.0  7.1610E-25
   162      162.0  8.0335E-25
   163      163.0  7.1334E-25
   164      164.0  6.3805E-25
   165      165.0  5.3121E-25
   166      166.0  7.0984E-25
   167      167.0  5.8294E-25
   168      168.0  7.6791E-25
   169      169.0  6.2975E-25
   170      170.0  6.8915E-25
   171      171.0  5.6785E-25
   172      172.0  5.7640E-25
   173      173.0  7.0625E-25
   174      174.0  6.3766E-25
   175      175.0  9.6069E-25
   176      176.0  8.4778E-25
   177      177.0  9.0836E-25
   178      178.0  3.2915E-25
   179      179.0  1.1871E-26
   180      180.0  1.3924E-39

 CPU TIME AFTER LEAVING GENDFDW    3.6793 S
 ALFREF,RFLUX          0.0    1.146E+14
0SURFACE TO SURFACE VISIBILITY MATRIX ISEE

 FTTTT
 TFFTF
 TFFFT
 TTFFT
 TFTTF

 MSCAT ARRAY FOR SURFACES:
 SURFACE   1   2   3   4   5
 MSCAT     T   T   T   T   T

 CPU TIME AFTER VISIBILITY MATRIX GENERATION   16.3261 S

 MONTE CARLO SCATTERING DATA

 AREA OF SMALLEST NODE =    6.3607E-02
   THIS NODE MAY HAVE UP TO          1 DIRECT AO RAYS SCATTERED FROM IT
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 AREA OF LARGEST NODE  =   2.5600E+00
   THIS NODE MAY HAVE UP TO          36 DIRECT AO RAYS SCATTERED FROM IT

 AREA OF AVERAGE NODE  =   7.1185E-01
   THIS NODE MAY HAVE UP TO          10 RAYS DIRECT AO SCATTERED FROM IT

 USING THE CURRENT VALUE OF MAXRAY =     10
         0 NODES OF         529 TOTAL NODES WILL HAVE NO DIRECT SOLAR RAYS
 SCATTERED FROM THEM

 CPU TIME AFTER PRECALCULATIONS   16.3300 S
0TOTAL RAYS INCLUDED IN PRECALCULATION =           96
0TOTAL RAYS INCLUDED IN THIS CALCULATION =     1955795

 CPU TIME AFTER FLUX CALCULATION       233.8938 S

 CPU TIME AFTER INTERPOLATION       234.2504
1 FLUX FOR EACH POINT

     FLUXES ARE CALCULATED FOR A DENSITY OF     1.55E+08 ATOMIC OXYGEN/CM**3
     FOR REFERENCE, AN UNSHIELDED FLAT SURFACE WITH NORMAL INCLINED      0.00 DEGREES TO RAM
DIRECTION
          RECEIVES A FLUX OF   1.15E+14 ATOMIC OXYGEN/CM**2/S
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SURFACE	TYPE	POINT	FLUXES (#/CM**2/S) PRIMARY	SPECULAR REFL	DIFFUSE REFL	RECOMB EFFICIENCY	SURFACE REACTIVITY	TOTAL	POSITION OF POINT X	Y	Z
1	TRAPEZOID	1	9.45E-15	3.51E+13	1.31E+12	0.00E+00	0.00E+00	3.64E+13	-3.984	-3.984	15.000
1	TRAPEZOID	2	9.31E-15	3.55E+13	1.73E+12	0.00E+00	0.00E+00	3.72E+13	-3.984	-2.384	15.000
1	TRAPEZOID	3	9.09E-15	3.55E+13	2.33E+12	0.00E+00	0.00E+00	3.78E+13	-3.984	-0.784	15.000
1	TRAPEZOID	4	9.10E-15	3.57E+13	2.34E+12	0.00E+00	0.00E+00	3.80E+13	-3.984	0.816	15.000
1	TRAPEZOID	5	9.31E-15	3.56E+13	1.64E+12	0.00E+00	0.00E+00	3.72E+13	-3.984	2.416	15.000
1	TRAPEZOID	6	9.45E-15	3.50E+13	1.16E+12	0.00E+00	0.00E+00	3.61E+13	-3.984	3.984	15.000
1	TRAPEZOID	7	9.31E-15	3.52E+13	1.57E+12	0.00E+00	0.00E+00	3.68E+13	-2.384	-3.984	15.000
1	TRAPEZOID	8	9.08E-15	3.02E+13	2.17E+12	0.00E+00	0.00E+00	3.23E+13	-2.384	-2.384	15.000
1	TRAPEZOID	9	8.83E-15	2.15E+13	3.03E+12	0.00E+00	0.00E+00	2.45E+13	-2.384	-0.784	15.000
1	TRAPEZOID	10	8.83E-15	2.18E+13	3.02E+12	0.00E+00	0.00E+00	2.48E+13	-2.384	0.816	15.000
1	TRAPEZOID	11	9.09E-15	3.10E+13	2.18E+12	0.00E+00	0.00E+00	3.32E+13	-2.384	2.416	15.000
1	TRAPEZOID	12	9.31E-15	3.61E+13	1.65E+12	0.00E+00	0.00E+00	3.78E+13	-2.384	3.984	15.000
1	TRAPEZOID	13	9.07E-15	3.54E+13	2.18E+12	0.00E+00	0.00E+00	3.76E+13	-0.784	-3.984	15.000
1	TRAPEZOID	14	8.74E-15	2.12E+13	2.81E+12	0.00E+00	0.00E+00	2.40E+13	-0.784	-2.384	15.000
1	TRAPEZOID	15	6.15E-15	3.77E+12	3.68E+12	0.00E+00	0.00E+00	7.46E+12	-0.784	-0.784	15.000
1	TRAPEZOID	16	6.27E-15	4.04E+12	3.88E+12	0.00E+00	0.00E+00	7.92E+12	-0.784	0.816	15.000
1	TRAPEZOID	17	8.75E-15	2.26E+13	2.87E+12	0.00E+00	0.00E+00	2.55E+13	-0.784	2.416	15.000
1	TRAPEZOID	18	9.07E-15	3.59E+13	2.05E+12	0.00E+00	0.00E+00	3.80E+13	-0.784	3.984	15.000
1	TRAPEZOID	19	9.07E-15	3.62E+13	2.13E+12	0.00E+00	0.00E+00	3.83E+13	0.816	-3.984	15.000
1	TRAPEZOID	20	8.74E-15	2.19E+13	2.81E+12	0.00E+00	0.00E+00	2.47E+13	0.816	-2.384	15.000
1	TRAPEZOID	21	6.27E-15	4.00E+12	3.67E+12	0.00E+00	0.00E+00	7.67E+12	0.816	-0.784	15.000
1	TRAPEZOID	22	6.39E-15	4.27E+12	3.68E+12	0.00E+00	0.00E+00	7.96E+12	0.816	0.816	15.000
1	TRAPEZOID	23	8.76E-15	2.23E+13	2.77E+12	0.00E+00	0.00E+00	2.51E+13	0.816	2.416	15.000
1	TRAPEZOID	24	9.07E-15	3.55E+13	2.16E+12	0.00E+00	0.00E+00	3.77E+13	0.816	3.984	15.000
1	TRAPEZOID	25	9.31E-15	3.63E+13	1.54E+12	0.00E+00	0.00E+00	3.79E+13	2.416	-3.984	15.000
1	TRAPEZOID	26	9.09E-15	3.11E+13	2.12E+12	0.00E+00	0.00E+00	3.33E+13	2.416	-2.384	15.000
1	TRAPEZOID	27	8.84E-15	2.24E+13	2.78E+12	0.00E+00	0.00E+00	2.51E+13	2.416	-0.784	15.000
1	TRAPEZOID	28	8.85E-15	2.28E+13	2.62E+12	0.00E+00	0.00E+00	2.54E+13	2.416	0.816	15.000
1	TRAPEZOID	29	9.10E-15	3.13E+13	2.02E+12	0.00E+00	0.00E+00	3.33E+13	2.416	2.416	15.000
1	TRAPEZOID	30	9.31E-15	3.57E+13	1.74E+12	0.00E+00	0.00E+00	3.75E+13	2.416	3.984	15.000
1	TRAPEZOID	31	9.45E-15	3.58E+13	1.36E+12	0.00E+00	0.00E+00	3.72E+13	3.984	-3.984	15.000
1	TRAPEZOID	32	9.31E-15	3.61E+13	1.65E+12	0.00E+00	0.00E+00	3.77E+13	3.984	-2.384	15.000
1	TRAPEZOID	33	9.09E-15	3.55E+13	1.95E+12	0.00E+00	0.00E+00	3.75E+13	3.984	-0.784	15.000
1	TRAPEZOID	34	9.10E-15	3.61E+13	2.00E+12	0.00E+00	0.00E+00	3.81E+13	3.984	0.816	15.000
1	TRAPEZOID	35	9.31E-15	3.62E+13	1.59E+12	0.00E+00	0.00E+00	3.78E+13	3.984	2.416	15.000
1	TRAPEZOID	36	9.45E-15	3.52E+13	1.18E+12	0.00E+00	0.00E+00	3.64E+13	3.984	3.984	15.000
2	CYLINDER	37	3.22E+12	3.37E+12	9.34E+12	6.70E+11	0.00E+00	1.59E+13	3.000	0.008	0.010
2	CYLINDER	38	2.95E+12	3.46E+12	9.25E+12	7.19E+11	0.00E+00	1.57E+13	2.896	0.784	0.010
2	CYLINDER	39	2.28E+12	3.46E+12	8.23E+12	7.73E+11	0.00E+00	1.40E+13	2.594	1.507	0.010
2	CYLINDER	40	1.93E+12	2.87E+12	7.78E+12	5.96E+11	0.00E+00	1.26E+13	2.116	2.127	0.010
2	CYLINDER	41	2.30E+12	2.65E+12	8.42E+12	5.45E+11	0.00E+00	1.34E+13	1.493	2.602	0.010
2	CYLINDER	42	2.97E+12	2.92E+12	9.55E+12	6.48E+11	0.00E+00	1.54E+13	0.769	2.900	0.010
2	CYLINDER	43	3.22E+12	2.97E+12	1.15E+13	8.90E+11	0.00E+00	1.77E+13	-0.008	3.000	0.010
2	CYLINDER	44	2.95E+12	2.67E+12	1.07E+13	9.89E+11	0.00E+00	1.63E+13	-0.784	2.896	0.010
2	CYLINDER	45	2.28E+12	2.70E+12	8.40E+12	6.59E+11	0.00E+00	1.34E+13	-1.507	2.594	0.010
2	CYLINDER	46	1.93E+12	3.09E+12	8.13E+12	5.08E+11	0.00E+00	1.31E+13	-2.127	2.116	0.010
2	CYLINDER	47	2.30E+12	3.28E+12	8.75E+12	7.41E+11	0.00E+00	1.43E+13	-2.602	1.493	0.010
2	CYLINDER	48	2.97E+12	3.37E+12	9.25E+12	8.74E+11	0.00E+00	1.56E+13	-2.900	0.769	0.010
2	CYLINDER	49	3.22E+12	3.06E+12	1.02E+13	7.47E+11	0.00E+00	1.65E+13	-3.000	-0.008	0.010
2	CYLINDER	50	2.95E+12	3.22E+12	1.03E+13	8.29E+11	0.00E+00	1.65E+13	-2.896	-0.784	0.010
2	CYLINDER	51	2.28E+12	3.30E+12	9.17E+12	7.98E+11	0.00E+00	1.48E+13	-2.594	-1.507	0.010
2	CYLINDER	52	1.93E+12	3.07E+12	8.80E+12	6.20E+11	0.00E+00	1.38E+13	-2.116	-2.127	0.010

2	CYLINDER	53	2.30E+12	3.14E+12	9.08E+12	6.24E+11	0.00E+00	1.45E+13	-1.493	-2.602	0.010
2	CYLINDER	54	2.97E+12	3.23E+12	9.71E+12	5.99E+11	0.00E+00	1.59E+13	-0.769	-2.900	0.010
2	CYLINDER	55	3.22E+12	3.59E+12	9.94E+12	7.69E+11	0.00E+00	1.68E+13	0.008	-3.000	0.010
2	CYLINDER	56	2.95E+12	4.01E+12	9.63E+12	9.18E+11	0.00E+00	1.66E+13	0.784	-2.896	0.010
2	CYLINDER	57	2.28E+12	3.32E+12	8.48E+12	7.95E+11	0.00E+00	1.41E+13	1.507	-2.594	0.010
2	CYLINDER	58	1.93E+12	2.67E+12	7.95E+12	6.77E+11	0.00E+00	1.25E+13	2.127	-2.116	0.010
2	CYLINDER	59	2.30E+12	3.08E+12	8.50E+12	7.59E+11	0.00E+00	1.39E+13	2.602	-1.493	0.010
2	CYLINDER	60	2.97E+12	3.38E+12	9.60E+12	8.61E+11	0.00E+00	1.59E+13	2.900	-0.769	0.010
2	CYLINDER	61	3.22E+12	3.40E+12	1.02E+13	7.90E+11	0.00E+00	1.68E+13	3.000	-0.008	0.010
2	CYLINDER	62	3.22E+12	3.16E+12	7.15E+12	7.54E+11	0.00E+00	1.35E+13	3.000	0.008	1.010
2	CYLINDER	63	2.95E+12	3.37E+12	6.76E+12	7.18E+11	0.00E+00	1.31E+13	2.896	0.784	1.010
2	CYLINDER	64	2.19E+12	3.38E+12	6.08E+12	5.28E+11	0.00E+00	1.17E+13	2.594	1.507	1.010
2	CYLINDER	65	1.77E+12	3.04E+12	5.91E+12	4.36E+11	0.00E+00	1.07E+13	2.116	2.127	1.010
2	CYLINDER	66	2.21E+12	2.97E+12	6.16E+12	4.58E+11	0.00E+00	1.13E+13	1.493	2.602	1.010
2	CYLINDER	67	2.96E+12	2.87E+12	6.85E+12	5.72E+11	0.00E+00	1.27E+13	0.769	2.900	1.010
2	CYLINDER	68	3.22E+12	2.94E+12	8.00E+12	7.23E+11	0.00E+00	1.41E+13	-0.008	3.000	1.010
2	CYLINDER	69	2.95E+12	3.07E+12	7.75E+12	7.23E+11	0.00E+00	1.38E+13	-0.784	2.896	1.010
2	CYLINDER	70	2.19E+12	2.77E+12	6.38E+12	5.60E+11	0.00E+00	1.13E+13	-1.507	2.594	1.010
2	CYLINDER	71	1.77E+12	2.66E+12	5.96E+12	3.99E+11	0.00E+00	1.04E+13	-2.127	2.116	1.010
2	CYLINDER	72	2.21E+12	3.04E+12	6.32E+12	4.82E+11	0.00E+00	1.16E+13	-2.602	1.493	1.010
2	CYLINDER	73	2.96E+12	3.32E+12	6.60E+12	6.40E+11	0.00E+00	1.29E+13	-2.900	0.769	1.010
2	CYLINDER	74	3.22E+12	3.09E+12	7.00E+12	6.78E+11	0.00E+00	1.33E+13	-3.000	-0.008	1.010
2	CYLINDER	75	2.95E+12	3.19E+12	7.13E+12	6.90E+11	0.00E+00	1.33E+13	-2.896	-0.784	1.010
2	CYLINDER	76	2.19E+12	3.23E+12	6.66E+12	5.65E+11	0.00E+00	1.21E+13	-2.594	-1.507	1.010
2	CYLINDER	77	1.77E+12	3.11E+12	6.34E+12	4.73E+11	0.00E+00	1.12E+13	-2.116	-2.127	1.010
2	CYLINDER	78	2.21E+12	3.28E+12	6.55E+12	5.60E+11	0.00E+00	1.20E+13	-1.493	-2.602	1.010
2	CYLINDER	79	2.96E+12	3.29E+12	7.06E+12	6.10E+11	0.00E+00	1.33E+13	-0.769	-2.900	1.010
2	CYLINDER	80	3.22E+12	3.41E+12	7.00E+12	6.40E+11	0.00E+00	1.36E+13	0.008	-3.000	1.010
2	CYLINDER	81	2.95E+12	3.54E+12	6.75E+12	5.96E+11	0.00E+00	1.32E+13	0.784	-2.896	1.010
2	CYLINDER	82	2.19E+12	3.17E+12	6.20E+12	5.57E+11	0.00E+00	1.16E+13	1.507	-2.594	1.010
2	CYLINDER	83	1.77E+12	2.99E+12	5.97E+12	5.57E+11	0.00E+00	1.07E+13	2.127	-2.116	1.010
2	CYLINDER	84	2.21E+12	3.31E+12	6.46E+12	5.46E+11	0.00E+00	1.20E+13	2.602	-1.493	1.010
2	CYLINDER	85	2.96E+12	3.33E+12	7.22E+12	5.77E+11	0.00E+00	1.35E+13	2.900	-0.769	1.010
2	CYLINDER	86	3.22E+12	3.18E+12	7.56E+12	6.40E+11	0.00E+00	1.39E+13	3.000	-0.008	1.010
2	CYLINDER	87	2.94E+12	3.19E+12	3.52E+12	5.99E+11	0.00E+00	9.65E+12	3.000	0.008	2.010
2	CYLINDER	88	2.80E+12	3.22E+12	3.41E+12	5.77E+11	0.00E+00	9.43E+12	2.896	0.784	2.010
2	CYLINDER	89	2.04E+12	3.15E+12	3.33E+12	3.30E+11	0.00E+00	8.51E+12	2.594	1.507	2.010
2	CYLINDER	90	1.51E+12	3.20E+12	3.31E+12	2.31E+11	0.00E+00	8.02E+12	2.116	2.127	2.010
2	CYLINDER	91	2.07E+12	3.16E+12	2.94E+12	3.04E+11	0.00E+00	8.17E+12	1.493	2.602	2.010
2	CYLINDER	92	2.81E+12	2.79E+12	3.00E+12	4.42E+11	0.00E+00	8.60E+12	0.769	2.900	2.010
2	CYLINDER	93	2.94E+12	3.01E+12	3.30E+12	5.29E+11	0.00E+00	9.25E+12	-0.008	3.000	2.010
2	CYLINDER	94	2.80E+12	3.64E+12	3.32E+12	5.01E+11	0.00E+00	9.77E+12	-0.784	2.896	2.010
2	CYLINDER	95	2.04E+12	3.18E+12	3.01E+12	4.63E+11	0.00E+00	8.23E+12	-1.507	2.594	2.010
2	CYLINDER	96	1.51E+12	2.69E+12	2.63E+12	3.04E+11	0.00E+00	6.84E+12	-2.127	2.116	2.010
2	CYLINDER	97	2.07E+12	3.07E+12	2.93E+12	3.20E+11	0.00E+00	8.07E+12	-2.602	1.493	2.010
2	CYLINDER	98	2.81E+12	3.15E+12	3.22E+12	5.14E+11	0.00E+00	9.17E+12	-2.900	0.769	2.010
2	CYLINDER	99	2.94E+12	2.94E+12	3.11E+12	5.42E+11	0.00E+00	8.98E+12	-3.000	-0.008	2.010
2	CYLINDER	100	2.80E+12	2.98E+12	2.94E+12	4.61E+11	0.00E+00	8.73E+12	-2.896	-0.784	2.010
2	CYLINDER	101	2.04E+12	3.02E+12	2.93E+12	3.70E+11	0.00E+00	7.99E+12	-2.594	-1.507	2.010
2	CYLINDER	102	1.51E+12	3.05E+12	2.75E+12	3.62E+11	0.00E+00	7.31E+12	-2.116	-2.127	2.010
2	CYLINDER	103	2.07E+12	3.18E+12	3.00E+12	4.64E+11	0.00E+00	8.26E+12	-1.493	-2.602	2.010
2	CYLINDER	104	2.81E+12	3.25E+12	3.59E+12	4.76E+11	0.00E+00	9.65E+12	-0.769	-2.900	2.010
2	CYLINDER	105	2.94E+12	3.30E+12	3.37E+12	4.75E+11	0.00E+00	9.61E+12	0.008	-3.000	2.010
2	CYLINDER	106	2.80E+12	3.10E+12	3.19E+12	3.61E+11	0.00E+00	9.09E+12	0.784	-2.896	2.010
2	CYLINDER	107	2.04E+12	3.00E+12	3.05E+12	3.34E+11	0.00E+00	8.09E+12	1.507	-2.594	2.010
2	CYLINDER	108	1.51E+12	3.23E+12	3.08E+12	3.84E+11	0.00E+00	7.83E+12	2.127	-2.116	2.010
2	CYLINDER	109	2.07E+12	3.33E+12	3.66E+12	3.79E+11	0.00E+00	9.06E+12	2.602	-1.493	2.010
2	CYLINDER	110	2.81E+12	3.24E+12	3.82E+12	3.80E+11	0.00E+00	9.87E+12	2.900	-0.769	2.010
2	CYLINDER	111	2.94E+12	3.19E+12	3.55E+12	4.37E+11	0.00E+00	9.68E+12	3.000	-0.008	2.010
2	CYLINDER	112	2.15E+12	3.35E+12	1.57E+12	2.71E+11	0.00E+00	7.07E+12	3.000	0.008	3.010
2	CYLINDER	113	2.15E+12	3.37E+12	1.64E+12	2.90E+11	0.00E+00	7.16E+12	2.896	0.784	3.010
2	CYLINDER	114	1.73E+12	3.12E+12	1.77E+12	3.03E+11	0.00E+00	6.62E+12	2.594	1.507	3.010
2	CYLINDER	115	1.33E+12	3.08E+12	1.80E+12	2.80E+11	0.00E+00	6.21E+12	2.116	2.127	3.010
2	CYLINDER	116	1.75E+12	3.03E+12	1.54E+12	3.11E+11	0.00E+00	6.33E+12	1.493	2.602	3.010
2	CYLINDER	117	2.15E+12	2.91E+12	1.45E+12	3.70E+11	0.00E+00	6.50E+12	0.769	2.900	3.010
2	CYLINDER	118	2.15E+12	3.22E+12	1.46E+12	3.78E+11	0.00E+00	6.83E+12	-0.008	3.000	3.010
2	CYLINDER	119	2.15E+12	3.68E+12	1.59E+12	3.81E+11	0.00E+00	7.41E+12	-0.784	2.896	3.010
2	CYLINDER	120	1.73E+12	3.44E+12	1.71E+12	3.44E+11	0.00E+00	6.88E+12	-1.507	2.594	3.010
2	CYLINDER	121	1.33E+12	3.10E+12	1.51E+12	2.99E+11	0.00E+00	5.94E+12	-2.127	2.116	3.010
2	CYLINDER	122	1.75E+12	3.18E+12	1.54E+12	3.61E+11	0.00E+00	6.48E+12	-2.602	1.493	3.010
2	CYLINDER	123	2.15E+12	3.30E+12	1.72E+12	5.02E+11	0.00E+00	7.17E+12	-2.900	0.769	3.010
2	CYLINDER	124	2.15E+12	3.18E+12	1.52E+12	3.98E+11	0.00E+00	6.85E+12	-3.000	-0.008	3.010
2	CYLINDER	125	2.15E+12	3.05E+12	1.28E+12	3.94E+11	0.00E+00	6.48E+12	-2.896	-0.784	3.010
2	CYLINDER	126	1.73E+12	2.87E+12	1.56E+12	4.17E+11	0.00E+00	6.16E+12	-2.594	-1.507	3.010
2	CYLINDER	127	1.33E+12	2.87E+12	1.58E+12	3.26E+11	0.00E+00	5.77E+12	-2.116	-2.127	3.010
2	CYLINDER	128	1.75E+12	3.10E+12	1.56E+12	3.31E+11	0.00E+00	6.42E+12	-1.493	-2.602	3.010
2	CYLINDER	129	2.15E+12	3.17E+12	1.80E+12	2.91E+11	0.00E+00	7.12E+12	-0.769	-2.900	3.010
2	CYLINDER	130	2.15E+12	3.24E+12	1.67E+12	3.39E+11	0.00E+00	7.05E+12	0.008	-3.000	3.010
2	CYLINDER	131	2.15E+12	3.33E+12	1.63E+12	3.60E+11	0.00E+00	7.10E+12	0.784	-2.896	3.010
2	CYLINDER	132	1.73E+12	3.43E+12	1.62E+12	3.31E+11	0.00E+00	6.78E+12	1.507	-2.594	3.010
2	CYLINDER	133	1.33E+12	3.28E+12	1.59E+12	3.43E+11	0.00E+00	6.20E+12	2.127	-2.116	3.010
2	CYLINDER	134	1.75E+12	2.97E+12	1.86E+12	3.64E+11	0.00E+00	6.58E+12	2.602	-1.493	3.010
2	CYLINDER	135	2.15E+12	2.96E+12	1.83E+12	3.35E+11	0.00E+00	6.93E+12	2.900	-0.769	3.010
2	CYLINDER	136	2.15E+12	3.14E+12	1.56E+12	3.00E+11	0.00E+00	6.84E+12	3.000	-0.008	3.010
2	CYLINDER	137	1.72E+12	3.62E+12	7.18E+11	3.51E+11	0.00E+00	6.06E+12	3.000	0.008	4.010
2	CYLINDER	138	1.60E+12	3.69E+12	6.38E+11	2.29E+11	0.00E+00	5.94E+12	2.896	0.784	4.010
2	CYLINDER	139	1.37E+12	3.32E+12	5.77E+11	2.11E+11	0.00E+00	5.26E+12	2.594	1.507	4.010
2	CYLINDER	140	1.26E+12	3.23E+12	7.26E+11	2.88E+11	0.00E+00	5.22E+12	2.116	2.127	4.010
2	CYLINDER	141	1.38E+12	3.38E+12	8.05E+11	3.16E+11	0.00E+00	5.56E+12	1.493	2.602	4.010
2	CYLINDER	142	1.61E+12	3.44E+12	7.14E+11	3.60E+11	0.00E+00	5.76E+12	0.769	2.900	4.010
2	CYLINDER	143	1.72E+12	3.32E+12	6.87E+11	2.86E+11	0.00E+00	5.74E+12	-0.008	3.000	4.010
2	CYLINDER	144	1.60E+12	3.29E+12	8.70E+11	2.48E+11	0.00E+00	5.77E+12	-0.784	2.896	4.010

2	CYLINDER	145	1.37E+12	3.05E+12	1.05E+12	2.37E+11	0.00E+00	5.47E+12	-1.507	2.594	4.010
2	CYLINDER	146	1.26E+12	2.76E+12	9.24E+11	2.45E+11	0.00E+00	4.95E+12	-2.127	2.116	4.010
2	CYLINDER	147	1.38E+12	3.12E+12	7.61E+11	3.22E+11	0.00E+00	5.26E+12	-2.602	1.493	4.010
2	CYLINDER	148	1.61E+12	3.43E+12	6.96E+11	3.51E+11	0.00E+00	5.74E+12	-2.900	0.769	4.010
2	CYLINDER	149	1.72E+12	3.39E+12	5.27E+11	2.70E+11	0.00E+00	5.65E+12	-3.000	-0.008	4.010
2	CYLINDER	150	1.60E+12	3.37E+12	5.38E+11	3.17E+11	0.00E+00	5.51E+12	-2.896	-0.784	4.010
2	CYLINDER	151	1.37E+12	3.09E+12	8.05E+11	3.39E+11	0.00E+00	5.27E+12	-2.594	-1.507	4.010
2	CYLINDER	152	1.26E+12	2.87E+12	8.47E+11	2.54E+11	0.00E+00	4.98E+12	-2.116	-2.127	4.010
2	CYLINDER	153	1.38E+12	3.21E+12	6.98E+11	2.47E+11	0.00E+00	5.28E+12	-1.493	-2.602	4.010
2	CYLINDER	154	1.61E+12	3.38E+12	6.00E+11	2.67E+11	0.00E+00	5.59E+12	-0.769	-2.900	4.010
2	CYLINDER	155	1.72E+12	3.38E+12	4.98E+11	3.04E+11	0.00E+00	5.60E+12	0.008	-3.000	4.010
2	CYLINDER	156	1.60E+12	3.62E+12	5.91E+11	3.16E+11	0.00E+00	5.82E+12	0.784	-2.896	4.010
2	CYLINDER	157	1.37E+12	3.42E+12	7.43E+11	2.83E+11	0.00E+00	5.53E+12	1.507	-2.594	4.010
2	CYLINDER	158	1.26E+12	3.12E+12	6.16E+11	3.26E+11	0.00E+00	5.00E+12	2.127	-2.116	4.010
2	CYLINDER	159	1.38E+12	2.93E+12	5.47E+11	2.95E+11	0.00E+00	4.85E+12	2.602	-1.493	4.010
2	CYLINDER	160	1.61E+12	2.97E+12	5.25E+11	2.85E+11	0.00E+00	5.10E+12	2.900	-0.769	4.010
2	CYLINDER	161	1.72E+12	3.38E+12	5.28E+11	3.58E+11	0.00E+00	5.63E+12	3.000	-0.008	4.010
2	CYLINDER	162	1.72E+12	3.92E+12	5.54E+11	4.83E+11	0.00E+00	6.19E+12	3.000	0.008	4.990
2	CYLINDER	163	1.54E+12	3.85E+12	5.36E+11	3.05E+11	0.00E+00	5.92E+12	2.896	0.784	4.990
2	CYLINDER	164	1.30E+12	3.41E+12	3.94E+11	1.88E+11	0.00E+00	5.10E+12	2.594	1.507	4.990
2	CYLINDER	165	1.26E+12	3.44E+12	5.08E+11	2.33E+11	0.00E+00	5.21E+12	2.116	2.127	4.990
2	CYLINDER	166	1.31E+12	3.69E+12	6.45E+11	2.70E+11	0.00E+00	5.64E+12	1.493	2.602	4.990
2	CYLINDER	167	1.55E+12	3.74E+12	5.61E+11	3.64E+11	0.00E+00	5.85E+12	0.769	2.900	4.990
2	CYLINDER	168	1.72E+12	3.33E+12	6.03E+11	3.03E+11	0.00E+00	5.66E+12	-0.008	3.000	4.990
2	CYLINDER	169	1.54E+12	3.04E+12	7.06E+11	2.54E+11	0.00E+00	5.28E+12	-0.784	2.896	4.990
2	CYLINDER	170	1.30E+12	2.75E+12	6.78E+11	2.39E+11	0.00E+00	4.73E+12	-1.507	2.594	4.990
2	CYLINDER	171	1.26E+12	2.50E+12	6.09E+11	2.14E+11	0.00E+00	4.37E+12	-2.127	2.116	4.990
2	CYLINDER	172	1.31E+12	3.18E+12	5.65E+11	3.20E+11	0.00E+00	5.05E+12	-2.602	1.493	4.990
2	CYLINDER	173	1.55E+12	3.33E+12	4.86E+11	3.20E+11	0.00E+00	5.37E+12	-2.900	0.769	4.990
2	CYLINDER	174	1.72E+12	3.23E+12	4.10E+11	2.35E+11	0.00E+00	5.36E+12	-3.000	-0.008	4.990
2	CYLINDER	175	1.54E+12	3.45E+12	4.72E+11	2.49E+11	0.00E+00	5.46E+12	-2.896	-0.784	4.990
2	CYLINDER	176	1.30E+12	3.30E+12	4.96E+11	2.52E+11	0.00E+00	5.10E+12	-2.594	-1.507	4.990
2	CYLINDER	177	1.26E+12	2.95E+12	4.69E+11	2.49E+11	0.00E+00	4.68E+12	-2.116	-2.127	4.990
2	CYLINDER	178	1.31E+12	3.19E+12	4.32E+11	2.56E+11	0.00E+00	4.92E+12	-1.493	-2.602	4.990
2	CYLINDER	179	1.55E+12	3.53E+12	4.26E+11	2.68E+11	0.00E+00	5.50E+12	-0.769	-2.900	4.990
2	CYLINDER	180	1.72E+12	3.63E+12	3.56E+11	3.55E+11	0.00E+00	5.70E+12	0.008	-3.000	4.990
2	CYLINDER	181	1.54E+12	3.71E+12	4.48E+11	3.30E+11	0.00E+00	5.70E+12	0.784	-2.896	4.990
2	CYLINDER	182	1.30E+12	3.04E+12	5.36E+11	2.48E+11	0.00E+00	4.88E+12	1.507	-2.594	4.990
2	CYLINDER	183	1.26E+12	2.89E+12	3.60E+11	3.15E+11	0.00E+00	4.51E+12	2.127	-2.116	4.990
2	CYLINDER	184	1.31E+12	3.00E+12	3.56E+11	2.82E+11	0.00E+00	4.66E+12	2.602	-1.493	4.990
2	CYLINDER	185	1.55E+12	3.19E+12	2.95E+11	3.37E+11	0.00E+00	5.03E+12	2.900	-0.769	4.990
2	CYLINDER	186	1.72E+12	3.85E+12	2.94E+11	4.84E+11	0.00E+00	5.86E+12	3.000	-0.008	4.990
3	CONE	187	7.11E+12	7.42E+12	1.75E+11	0.00E+00	1.36E+12	1.47E+13	2.995	0.008	5.008
3	CONE	188	6.09E+12	7.23E+12	1.64E+11	0.00E+00	1.31E+12	1.35E+13	2.891	0.783	5.008
3	CONE	189	3.57E+12	7.56E+12	2.49E+11	0.00E+00	1.16E+12	1.14E+13	2.590	1.504	5.008
3	CONE	190	2.26E+12	8.38E+12	3.05E+11	0.00E+00	1.27E+12	1.09E+13	2.113	2.124	5.008
3	CONE	191	3.63E+12	7.51E+12	2.59E+11	0.00E+00	1.50E+12	1.14E+13	1.491	2.598	5.008
3	CONE	192	6.14E+12	7.08E+12	1.96E+11	0.00E+00	1.72E+12	1.34E+13	0.768	2.895	5.008
3	CONE	193	7.11E+12	7.16E+12	1.19E+11	0.00E+00	1.67E+12	1.44E+13	-0.008	2.995	5.008
3	CONE	194	6.09E+12	6.86E+12	2.12E+11	0.00E+00	1.23E+12	1.32E+13	-0.783	2.891	5.008
3	CONE	195	3.57E+12	8.18E+12	3.53E+11	0.00E+00	1.16E+12	1.21E+13	-1.504	2.590	5.008
3	CONE	196	2.26E+12	8.84E+12	3.35E+11	0.00E+00	9.33E+11	1.14E+13	-2.124	2.113	5.008
3	CONE	197	3.63E+12	7.79E+12	2.80E+11	0.00E+00	9.72E+11	1.17E+13	-2.598	1.491	5.008
3	CONE	198	6.14E+12	6.44E+12	3.24E+11	0.00E+00	1.25E+12	1.29E+13	-2.895	0.768	5.008
3	CONE	199	7.11E+12	7.65E+12	3.41E+11	0.00E+00	1.48E+12	1.51E+13	-2.995	-0.008	5.008
3	CONE	200	6.09E+12	8.31E+12	1.86E+11	0.00E+00	1.30E+12	1.46E+13	-2.891	-0.783	5.008
3	CONE	201	3.57E+12	7.29E+12	1.79E+11	0.00E+00	9.77E+11	1.10E+13	-2.590	-1.504	5.008
3	CONE	202	2.26E+12	7.57E+12	1.97E+11	0.00E+00	1.03E+12	1.00E+13	-2.113	-2.124	5.008
3	CONE	203	3.63E+12	7.12E+12	1.41E+11	0.00E+00	8.54E+11	1.09E+13	-1.491	-2.598	5.008
3	CONE	204	6.14E+12	6.59E+12	2.19E+11	0.00E+00	1.08E+12	1.30E+13	-0.768	-2.895	5.008
3	CONE	205	7.11E+12	6.36E+12	2.35E+11	0.00E+00	1.41E+12	1.37E+13	0.008	-2.995	5.008
3	CONE	206	6.09E+12	6.58E+12	2.57E+11	0.00E+00	1.31E+12	1.29E+13	0.783	-2.891	5.008
3	CONE	207	3.57E+12	6.95E+12	2.85E+11	0.00E+00	9.59E+11	1.08E+13	1.504	-2.590	5.008
3	CONE	208	2.26E+12	7.36E+12	1.59E+11	0.00E+00	9.20E+11	9.78E+12	2.124	-2.113	5.008
3	CONE	209	3.63E+12	6.51E+12	1.40E+11	0.00E+00	1.03E+12	1.03E+13	2.598	-1.491	5.008
3	CONE	210	6.14E+12	6.23E+12	1.80E+11	0.00E+00	1.17E+12	1.25E+13	2.895	-0.768	5.008
3	CONE	211	7.11E+12	7.35E+12	1.66E+11	0.00E+00	1.36E+12	1.46E+13	2.995	-0.008	5.008
3	CONE	212	3.97E+12	6.48E+12	3.67E+11	0.00E+00	9.45E+11	1.08E+13	2.495	0.007	5.841
3	CONE	213	3.42E+12	6.52E+12	3.31E+11	0.00E+00	8.59E+11	1.03E+13	2.409	0.652	5.841
3	CONE	214	2.08E+12	7.10E+12	2.53E+11	0.00E+00	8.50E+11	9.44E+12	2.158	1.253	5.841
3	CONE	215	1.38E+12	7.92E+12	2.35E+11	0.00E+00	1.01E+12	9.53E+12	1.760	1.769	5.841
3	CONE	216	2.12E+12	7.39E+12	2.33E+11	0.00E+00	1.11E+12	9.74E+12	1.242	2.164	5.841
3	CONE	217	3.44E+12	6.81E+12	2.24E+11	0.00E+00	1.18E+12	1.05E+13	0.640	2.412	5.841
3	CONE	218	3.98E+12	6.77E+12	1.52E+11	0.00E+00	1.18E+12	1.09E+13	-0.007	2.495	5.841
3	CONE	219	3.42E+12	6.64E+12	2.80E+11	0.00E+00	1.12E+12	1.03E+13	-0.652	2.409	5.841
3	CONE	220	2.08E+12	7.41E+12	3.54E+11	0.00E+00	1.05E+12	9.85E+12	-1.253	2.158	5.841
3	CONE	221	1.38E+12	7.65E+12	2.89E+11	0.00E+00	8.13E+11	9.32E+12	-1.769	1.760	5.841
3	CONE	222	2.12E+12	6.44E+12	3.25E+11	0.00E+00	7.77E+11	8.88E+12	-2.164	1.242	5.841
3	CONE	223	3.44E+12	5.97E+12	3.42E+11	0.00E+00	9.00E+11	9.76E+12	-2.412	0.640	5.841
3	CONE	224	3.98E+12	7.00E+12	3.20E+11	0.00E+00	9.91E+11	1.13E+13	-2.495	-0.007	5.841
3	CONE	225	3.42E+12	7.15E+12	2.33E+11	0.00E+00	8.76E+11	1.08E+13	-2.409	-0.652	5.841
3	CONE	226	2.08E+12	6.66E+12	1.95E+11	0.00E+00	8.66E+11	8.95E+12	-2.158	-1.253	5.841
3	CONE	227	1.38E+12	7.20E+12	1.98E+11	0.00E+00	9.74E+11	8.78E+12	-1.760	-1.769	5.841
3	CONE	228	2.12E+12	6.76E+12	2.63E+11	0.00E+00	8.72E+11	9.14E+12	-1.242	-2.164	5.841
3	CONE	229	3.44E+12	6.36E+12	2.67E+11	0.00E+00	1.07E+12	1.01E+13	-0.640	-2.412	5.841
3	CONE	230	3.98E+12	6.45E+12	1.86E+11	0.00E+00	1.31E+12	1.06E+13	0.007	-2.495	5.841
3	CONE	231	3.42E+12	6.64E+12	2.59E+11	0.00E+00	1.14E+12	1.03E+13	0.652	-2.409	5.841
3	CONE	232	2.08E+12	6.82E+12	3.30E+11	0.00E+00	8.95E+11	9.24E+12	1.253	-2.158	5.841
3	CONE	233	1.38E+12	6.99E+12	2.68E+11	0.00E+00	8.37E+11	8.64E+12	1.769	-1.760	5.841
3	CONE	234	2.12E+12	6.35E+12	1.97E+11	0.00E+00	8.15E+11	8.67E+12	2.164	-1.242	5.841
3	CONE	235	3.44E+12	6.03E+12	1.93E+11	0.00E+00	1.01E+12	9.67E+12	2.412	-0.640	5.841
3	CONE	236	3.98E+12	6.60E+12	2.70E+11	0.00E+00	1.11E+12	1.08E+13	2.495	-0.007	5.841

3	CONE	237	4.82E+11	3.16E+12	4.44E+11	0.00E+00	3.01E+11	4.08E+12	1.996	0.005	6.674
3	CONE	238	4.28E+11	3.33E+12	4.02E+11	0.00E+00	2.47E+11	4.16E+12	1.926	0.522	6.674
3	CONE	239	2.97E+11	3.90E+12	3.05E+11	0.00E+00	3.33E+11	4.50E+12	1.726	1.002	6.674
3	CONE	240	2.20E+11	4.16E+12	2.71E+11	0.00E+00	4.40E+11	4.65E+12	1.407	1.415	6.674
3	CONE	241	2.99E+11	4.06E+12	3.48E+11	0.00E+00	3.63E+11	4.71E+12	0.993	1.731	6.674
3	CONE	242	4.30E+11	3.65E+12	3.83E+11	0.00E+00	3.39E+11	4.46E+12	0.511	1.929	6.674
3	CONE	243	4.93E+11	3.57E+12	3.35E+11	0.00E+00	4.06E+11	4.40E+12	-0.005	1.996	6.674
3	CONE	244	4.28E+11	3.84E+12	3.60E+11	0.00E+00	5.73E+11	4.63E+12	-0.522	1.926	6.674
3	CONE	245	2.97E+11	3.85E+12	3.58E+11	0.00E+00	6.01E+11	4.50E+12	-1.002	1.726	6.674
3	CONE	246	2.20E+11	3.73E+12	3.33E+11	0.00E+00	4.40E+11	4.28E+12	-1.415	1.407	6.674
3	CONE	247	2.99E+11	3.16E+12	3.39E+11	0.00E+00	3.57E+11	3.80E+12	-1.731	0.993	6.674
3	CONE	248	4.30E+11	3.25E+12	2.90E+11	0.00E+00	3.22E+11	3.97E+12	-1.929	0.511	6.674
3	CONE	249	4.93E+11	3.58E+12	3.07E+11	0.00E+00	2.89E+11	4.38E+12	-1.996	-0.005	6.674
3	CONE	250	4.28E+11	3.39E+12	3.60E+11	0.00E+00	2.72E+11	4.18E+12	-1.926	-0.522	6.674
3	CONE	251	2.97E+11	3.45E+12	2.94E+11	0.00E+00	4.59E+11	4.04E+12	-1.726	-1.002	6.674
3	CONE	252	2.20E+11	3.90E+12	3.03E+11	0.00E+00	5.39E+11	4.42E+12	-1.407	-1.415	6.674
3	CONE	253	2.99E+11	3.84E+12	4.39E+11	0.00E+00	5.06E+11	4.57E+12	-0.993	-1.731	6.674
3	CONE	254	4.30E+11	3.55E+12	3.44E+11	0.00E+00	5.94E+11	4.32E+12	-0.511	-1.929	6.674
3	CONE	255	4.93E+11	3.75E+12	2.16E+11	0.00E+00	6.53E+11	4.45E+12	0.005	-1.996	6.674
3	CONE	256	4.28E+11	3.91E+12	3.42E+11	0.00E+00	5.37E+11	4.68E+12	0.522	-1.926	6.674
3	CONE	257	2.97E+11	3.90E+12	3.98E+11	0.00E+00	5.09E+11	4.60E+12	1.002	-1.726	6.674
3	CONE	258	2.20E+11	3.95E+12	3.27E+11	0.00E+00	5.30E+11	4.50E+12	1.415	-1.407	6.674
3	CONE	259	2.99E+11	3.60E+12	1.89E+11	0.00E+00	3.92E+11	4.09E+12	1.731	-0.993	6.674
3	CONE	260	4.30E+11	3.24E+12	2.20E+11	0.00E+00	3.88E+11	3.89E+12	1.929	-0.511	6.674
3	CONE	261	4.93E+11	3.22E+12	3.80E+11	0.00E+00	4.25E+11	4.10E+12	1.996	-0.005	6.674
3	CONE	262	4.34E+10	4.52E+11	3.37E+11	0.00E+00	1.28E+11	8.32E+11	1.496	0.004	7.507
3	CONE	263	3.93E+10	4.82E+11	2.75E+11	0.00E+00	8.51E+10	7.97E+11	1.444	0.391	7.507
3	CONE	264	2.30E+10	5.83E+11	3.14E+11	0.00E+00	6.07E+10	9.20E+11	1.293	0.751	7.507
3	CONE	265	1.18E+10	4.77E+11	3.99E+11	0.00E+00	9.71E+10	8.88E+11	1.055	1.060	7.507
3	CONE	266	2.34E+10	4.26E+11	4.51E+11	0.00E+00	4.60E+10	9.01E+11	0.745	1.297	7.507
3	CONE	267	3.95E+10	4.05E+11	3.66E+11	0.00E+00	3.93E+10	8.11E+11	0.383	1.446	7.507
3	CONE	268	4.48E+10	4.13E+11	3.56E+11	0.00E+00	9.20E+10	8.13E+11	-0.004	1.496	7.507
3	CONE	269	3.93E+10	5.89E+11	2.63E+11	0.00E+00	8.66E+10	8.92E+11	-0.391	1.444	7.507
3	CONE	270	2.30E+10	5.79E+11	3.08E+11	0.00E+00	1.71E+11	9.11E+11	-0.751	1.293	7.507
3	CONE	271	1.18E+10	5.63E+11	4.35E+11	0.00E+00	1.85E+11	1.01E+12	-1.060	1.055	7.507
3	CONE	272	2.34E+10	5.68E+11	3.54E+11	0.00E+00	9.09E+10	9.45E+11	-1.297	0.745	7.507
3	CONE	273	3.95E+10	5.14E+11	2.15E+11	0.00E+00	5.03E+10	7.68E+11	-1.446	0.383	7.507
3	CONE	274	4.48E+10	4.69E+11	2.84E+11	0.00E+00	4.30E+10	7.98E+11	-1.496	-0.004	7.507
3	CONE	275	3.93E+10	4.68E+11	4.67E+11	0.00E+00	9.93E+10	9.74E+11	-1.444	-0.391	7.507
3	CONE	276	2.30E+10	4.84E+11	4.13E+11	0.00E+00	1.26E+11	9.20E+11	-1.293	-0.751	7.507
3	CONE	277	1.18E+10	5.03E+11	3.37E+11	0.00E+00	7.96E+10	8.52E+11	-1.055	-1.060	7.507
3	CONE	278	2.34E+10	6.14E+11	3.47E+11	0.00E+00	4.93E+10	9.85E+11	-0.745	-1.297	7.507
3	CONE	279	3.95E+10	4.77E+11	3.81E+11	0.00E+00	8.37E+10	8.98E+11	-0.383	-1.446	7.507
3	CONE	280	4.48E+10	4.15E+11	3.80E+11	0.00E+00	9.36E+10	8.40E+11	0.004	-1.496	7.507
3	CONE	281	3.93E+10	4.87E+11	4.34E+11	0.00E+00	8.81E+10	9.60E+11	0.391	-1.444	7.507
3	CONE	282	2.30E+10	5.22E+11	3.00E+11	0.00E+00	1.09E+11	8.45E+11	0.751	-1.293	7.507
3	CONE	283	1.18E+10	6.25E+11	2.32E+11	0.00E+00	1.77E+11	8.69E+11	1.060	-1.055	7.507
3	CONE	284	2.34E+10	4.82E+11	2.39E+11	0.00E+00	8.92E+10	7.45E+11	1.297	-0.745	7.507
3	CONE	285	3.95E+10	3.45E+11	3.58E+11	0.00E+00	3.74E+10	7.43E+11	1.446	-0.383	7.507
3	CONE	286	4.48E+10	3.88E+11	4.66E+11	0.00E+00	9.33E+10	8.98E+11	1.496	-0.004	7.507
3	CONE	287	1.02E+09	1.65E-14	2.86E+11	0.00E+00	5.92E+10	2.87E+11	0.996	0.003	8.340
3	CONE	288	8.70E+08	0.00E+00	2.40E+11	0.00E+00	2.23E+10	2.41E+11	0.962	0.260	8.340
3	CONE	289	6.04E+08	0.00E+00	3.10E+11	0.00E+00	6.49E-02	3.11E+11	0.861	0.500	8.340
3	CONE	290	4.88E+08	5.33E+06	3.92E+11	0.00E+00	2.13E+10	3.92E+11	0.703	0.706	8.340
3	CONE	291	6.08E+08	5.05E+06	3.64E+11	0.00E+00	2.58E+10	3.65E+11	0.496	0.864	8.340
3	CONE	292	8.76E+08	0.00E+00	2.53E+11	0.00E+00	1.05E+10	2.54E+11	0.255	0.963	8.340
3	CONE	293	1.06E+09	1.88E+01	3.11E+11	0.00E+00	2.39E+10	3.12E+11	-0.003	0.996	8.340
3	CONE	294	8.70E+08	1.78E+01	3.71E+11	0.00E+00	6.19E+10	3.71E+11	-0.260	0.962	8.340
3	CONE	295	6.04E+08	0.00E+00	3.85E+11	0.00E+00	8.50E+10	3.85E+11	-0.500	0.861	8.340
3	CONE	296	4.88E+08	0.00E+00	3.12E+11	0.00E+00	6.81E+10	3.12E+11	-0.706	0.703	8.340
3	CONE	297	6.08E+08	8.86E-06	3.25E+11	0.00E+00	1.77E+10	3.26E+11	-0.864	0.496	8.340
3	CONE	298	8.76E+08	0.00E+00	3.50E+11	0.00E+00	3.97E+09	3.51E+11	-0.963	0.255	8.340
3	CONE	299	1.06E+09	5.75E-16	2.47E+11	0.00E+00	2.42E+10	2.48E+11	-0.996	-0.003	8.340
3	CONE	300	8.70E+08	2.29E-17	2.87E+11	0.00E+00	8.77E+10	2.88E+11	-0.962	-0.260	8.340
3	CONE	301	6.04E+08	0.00E+00	4.49E+11	0.00E+00	8.32E+10	4.49E+11	-0.861	-0.500	8.340
3	CONE	302	4.88E+08	1.68E-06	4.57E+11	0.00E+00	4.09E+07	4.57E+11	-0.703	-0.706	8.340
3	CONE	303	6.08E+08	1.88E+07	3.57E+11	0.00E+00	1.57E+10	3.57E+11	-0.496	-0.864	8.340
3	CONE	304	8.76E+08	1.78E+07	2.87E+11	0.00E+00	4.16E+10	2.88E+11	-0.255	-0.963	8.340
3	CONE	305	1.06E+09	1.89E+07	3.09E+11	0.00E+00	2.36E+10	3.10E+11	0.003	-0.996	8.340
3	CONE	306	8.70E+08	1.79E+07	2.84E+11	0.00E+00	8.84E+09	2.85E+11	0.260	-0.962	8.340
3	CONE	307	6.04E+08	0.00E+00	1.17E+11	0.00E+00	7.96E+09	1.17E+11	0.500	-0.861	8.340
3	CONE	308	4.88E+08	0.00E+00	2.52E+11	0.00E+00	9.75E+09	2.53E+11	0.706	-0.703	8.340
3	CONE	309	6.08E+08	6.93E+00	3.11E+11	0.00E+00	9.76E+09	3.12E+11	0.864	-0.496	8.340
3	CONE	310	8.76E+08	6.57E+00	3.74E+11	0.00E+00	3.18E+10	3.75E+11	0.963	-0.255	8.340
3	CONE	311	1.06E+09	7.92E-15	4.82E+11	0.00E+00	6.14E+10	4.83E+11	0.996	-0.003	8.340
3	CONE	312	8.60E+06	1.54E-14	4.43E+11	0.00E+00	3.69E+06	4.43E+11	0.497	0.001	9.171
3	CONE	313	6.71E+06	9.09E-08	3.28E+11	0.00E+00	2.52E+06	3.28E+11	0.480	0.130	9.171
3	CONE	314	3.21E+06	8.54E-08	1.61E+11	0.00E+00	5.63E+07	1.61E+11	0.430	0.250	9.171
3	CONE	315	1.50E+06	6.57E-01	2.49E+11	0.00E+00	5.33E+07	2.49E+11	0.351	0.353	9.171
3	CONE	316	3.27E+06	6.23E-01	2.23E+11	0.00E+00	2.63E+05	2.23E+11	0.248	0.431	9.171
3	CONE	317	6.79E+06	2.89E+00	1.25E+11	0.00E+00	7.35E+09	1.25E+11	0.128	0.481	9.171
3	CONE	318	9.07E+06	2.04E+01	1.75E+11	0.00E+00	5.52E+09	1.75E+11	-0.001	0.497	9.171
3	CONE	319	6.71E+06	1.67E+01	2.92E+11	0.00E+00	4.55E+10	2.92E+11	-0.130	0.480	9.171
3	CONE	320	3.21E+06	2.78E-03	2.67E+11	0.00E+00	4.29E+10	2.67E+11	-0.250	0.430	9.171
3	CONE	321	1.50E+06	2.64E-03	8.81E+10	0.00E+00	1.14E+05	8.81E+10	-0.353	0.351	9.171
3	CONE	322	3.27E+06	1.09E-06	3.35E+11	0.00E+00	2.08E+11	3.35E+11	-0.431	0.248	9.171
3	CONE	323	6.79E+06	1.02E-06	4.24E+11	0.00E+00	2.20E+11	4.24E+11	-0.481	0.128	9.171
3	CONE	324	9.07E+06	5.34E-16	1.16E+11	0.00E+00	2.27E+10	1.16E+11	-0.497	-0.001	9.171
3	CONE	325	6.71E+06	1.73E-17	3.78E+10	0.00E+00	4.55E+10	3.78E+10	-0.480	-0.130	9.171
3	CONE	326	3.21E+06	2.55E-13	2.01E+11	0.00E+00	4.34E+10	2.01E+11	-0.430	-0.250	9.171
3	CONE	327	1.50E+06	2.43E-13	3.04E+11	0.00E+00	7.65E-02	3.04E+11	-0.351	-0.353	9.171
3	CONE	328	3.27E+06	1.76E+07	2.33E+11	0.00E+00	1.47E+10	2.33E+11	-0.248	-0.431	9.171

3	CONE	329	6.79E+06	1.67E+07	2.40E+11	0.00E+00	2.13E+10	2.40E+11	-0.128	-0.481	9.171
3	CONE	330	9.07E+06	1.77E+07	2.16E+11	0.00E+00	5.76E+09	2.16E+11	0.001	-0.497	9.171
3	CONE	331	6.71E+06	1.67E+07	2.78E+11	0.00E+00	6.49E+05	2.78E+11	0.130	-0.480	9.171
3	CONE	332	3.21E+06	9.88E-08	2.25E+11	0.00E+00	3.19E+05	2.25E+11	0.250	-0.430	9.171
3	CONE	333	1.50E+06	9.37E-08	1.55E+11	0.00E+00	1.50E+05	1.55E+11	0.353	-0.351	9.171
3	CONE	334	3.27E+06	4.96E-18	1.30E+11	0.00E+00	3.26E+05	1.30E+11	0.431	-0.248	9.171
3	CONE	335	6.79E+06	6.81E-19	1.30E+11	0.00E+00	6.73E+05	1.30E+11	0.481	-0.128	9.171
3	CONE	336	9.07E+06	7.42E-15	2.99E+11	0.00E+00	2.31E+06	2.99E+11	0.497	-0.001	9.171
3	CONE	337	6.49E-01	0.00E+00	6.30E+11	0.00E+00	3.89E+06	6.30E+11	0.050	0.000	9.917
3	CONE	338	6.49E-01	1.77E-07	4.02E+11	0.00E+00	2.46E+06	4.02E+11	0.048	0.013	9.917
3	CONE	339	6.49E-01	1.67E-07	3.25E-12	0.00E+00	1.09E+08	6.49E-01	0.043	0.025	9.917
3	CONE	340	6.49E-01	9.84E-07	1.48E+11	0.00E+00	1.03E+08	1.48E+11	0.035	0.035	9.917
3	CONE	341	6.49E-01	9.19E-07	1.40E+11	0.00E+00	6.49E-02	1.40E+11	0.025	0.043	9.917
3	CONE	342	6.49E-01	5.65E+00	3.25E-12	0.00E+00	6.49E-02	6.30E+00	0.013	0.048	9.917
3	CONE	343	6.49E-01	5.35E+00	5.46E+07	0.00E+00	6.49E-02	5.46E+07	-0.000	0.050	9.917
3	CONE	344	6.49E-01	0.00E+00	4.55E+10	0.00E+00	6.49E-02	4.55E+10	-0.013	0.048	9.917
3	CONE	345	6.49E-01	5.42E-03	4.28E+10	0.00E+00	6.49E-02	4.28E+10	-0.025	0.043	9.917
3	CONE	346	6.49E-01	5.14E-03	3.25E-12	0.00E+00	6.49E-02	6.54E-01	-0.035	0.035	9.917
3	CONE	347	6.49E-01	2.13E-06	4.05E+11	0.00E+00	4.05E+11	4.05E+11	-0.043	0.025	9.917
3	CONE	348	6.49E-01	1.99E-06	3.82E+11	0.00E+00	3.81E+11	3.82E+11	-0.048	0.013	9.917
3	CONE	349	6.49E-01	0.00E+00	3.25E-12	0.00E+00	5.26E+07	6.49E-01	-0.050	-0.000	9.917
3	CONE	350	6.49E-01	0.00E+00	3.29E+09	0.00E+00	6.49E-02	3.29E+09	-0.048	-0.013	9.917
3	CONE	351	6.49E-01	4.98E-13	3.14E+09	0.00E+00	6.49E-02	3.14E+09	-0.043	-0.025	9.917
3	CONE	352	6.49E-01	4.72E-13	3.25E-12	0.00E+00	8.74E-02	6.49E-01	-0.035	-0.035	9.917
3	CONE	353	6.49E-01	2.03E-16	2.33E+09	0.00E+00	8.62E-02	2.33E+09	-0.025	-0.043	9.917
3	CONE	354	6.49E-01	2.48E-18	2.83E+11	0.00E+00	6.49E-02	2.83E+11	-0.013	-0.048	9.917
3	CONE	355	6.49E-01	2.32E-18	2.64E+11	0.00E+00	6.49E-02	2.64E+11	0.000	-0.050	9.917
3	CONE	356	6.49E-01	0.00E+00	4.05E+11	0.00E+00	6.49E-02	4.05E+11	0.013	-0.048	9.917
3	CONE	357	6.49E-01	1.93E-07	3.81E+11	0.00E+00	6.49E-02	3.81E+11	0.025	-0.043	9.917
3	CONE	358	6.49E-01	1.83E-07	3.18E+09	0.00E+00	6.49E-02	3.18E+09	0.035	-0.035	9.917
3	CONE	359	6.49E-01	6.59E-18	8.94E+09	0.00E+00	6.49E-02	8.94E+09	0.043	-0.025	9.917
3	CONE	360	6.49E-01	0.00E+00	5.29E+09	0.00E+00	6.49E-02	5.29E+09	0.048	-0.013	9.917
3	CONE	361	6.49E-01	0.00E+00	1.97E+11	0.00E+00	1.87E+06	1.97E+11	0.050	-0.000	9.917
4	DISK	362	1.03E+14	1.92E+12	1.66E+12	5.24E+12	0.00E+00	1.06E+14	5.993	-0.016	0.000
4	DISK	363	1.03E+14	2.06E+12	1.45E+12	5.24E+12	0.00E+00	1.06E+14	5.785	-1.566	0.000
4	DISK	364	9.34E+13	2.53E+12	1.09E+12	4.74E+12	0.00E+00	9.70E+13	5.182	-3.010	0.000
4	DISK	365	8.46E+13	2.53E+12	1.29E+12	4.36E+12	0.00E+00	8.84E+13	4.227	-4.249	0.000
4	DISK	366	9.39E+13	2.20E+12	1.25E+12	4.88E+12	0.00E+00	9.73E+13	2.983	-5.198	0.000
4	DISK	367	1.03E+14	2.20E+12	1.20E+12	5.37E+12	0.00E+00	1.06E+14	1.536	-5.793	0.000
4	DISK	368	1.03E+14	1.82E+12	1.16E+12	5.37E+12	0.00E+00	1.06E+14	-0.016	-5.993	0.000
4	DISK	369	1.03E+14	2.09E+12	1.03E+12	5.28E+12	0.00E+00	1.06E+14	-1.566	-5.785	0.000
4	DISK	370	9.34E+13	2.23E+12	9.33E+11	4.77E+12	0.00E+00	9.65E+13	-3.010	-5.182	0.000
4	DISK	371	8.46E+13	2.34E+12	9.22E+11	4.38E+12	0.00E+00	8.79E+13	-4.249	-4.227	0.000
4	DISK	372	9.39E+13	2.34E+12	9.96E+11	4.88E+12	0.00E+00	9.72E+13	-5.198	-2.983	0.000
4	DISK	373	1.03E+14	1.97E+12	1.04E+12	5.30E+12	0.00E+00	1.06E+14	-5.793	-1.536	0.000
4	DISK	374	1.03E+14	1.89E+12	1.08E+12	5.22E+12	0.00E+00	1.06E+14	-5.993	0.016	0.000
4	DISK	375	1.03E+14	2.06E+12	8.89E+11	5.19E+12	0.00E+00	1.06E+14	-5.785	1.566	0.000
4	DISK	376	9.34E+13	2.02E+12	1.20E+12	4.78E+12	0.00E+00	9.66E+13	-5.182	3.010	0.000
4	DISK	377	8.46E+13	1.80E+12	1.55E+12	4.39E+12	0.00E+00	8.80E+13	-4.227	4.249	0.000
4	DISK	378	9.39E+13	2.11E+12	1.47E+12	5.07E+12	0.00E+00	9.75E+13	-2.983	5.198	0.000
4	DISK	379	1.03E+14	2.14E+12	1.37E+12	5.43E+12	0.00E+00	1.06E+14	-1.536	5.793	0.000
4	DISK	380	1.03E+14	2.17E+12	1.12E+12	5.24E+12	0.00E+00	1.06E+14	0.016	5.993	0.000
4	DISK	381	1.03E+14	2.26E+12	1.02E+12	5.31E+12	0.00E+00	1.06E+14	1.566	5.785	0.000
4	DISK	382	9.34E+13	2.16E+12	1.25E+12	4.83E+12	0.00E+00	9.68E+13	3.010	5.182	0.000
4	DISK	383	8.46E+13	2.08E+12	1.21E+12	4.32E+12	0.00E+00	8.79E+13	4.249	4.227	0.000
4	DISK	384	9.39E+13	2.06E+12	1.10E+12	4.74E+12	0.00E+00	9.70E+13	5.198	2.983	0.000
4	DISK	385	1.03E+14	1.86E+12	1.02E+12	5.17E+12	0.00E+00	1.06E+14	5.793	1.536	0.000
4	DISK	386	1.03E+14	1.75E+12	1.11E+12	5.21E+12	0.00E+00	1.06E+14	5.993	0.016	0.000
4	DISK	387	9.16E+13	2.53E+12	1.33E+12	4.74E+12	0.00E+00	9.55E+13	5.243	-0.014	0.000
4	DISK	388	8.94E+13	2.84E+12	1.28E+12	4.64E+12	0.00E+00	9.36E+13	5.061	-1.370	0.000
4	DISK	389	8.17E+13	3.46E+12	1.33E+12	4.30E+12	0.00E+00	8.65E+13	4.534	-2.633	0.000
4	DISK	390	7.75E+13	3.37E+12	1.59E+12	4.18E+12	0.00E+00	8.25E+13	3.698	-3.717	0.000
4	DISK	391	8.20E+13	3.18E+12	1.43E+12	4.38E+12	0.00E+00	8.66E+13	2.610	-4.547	0.000
4	DISK	392	8.95E+13	2.78E+12	1.29E+12	4.72E+12	0.00E+00	9.36E+13	1.344	-5.068	0.000
4	DISK	393	9.17E+13	2.39E+12	1.27E+12	4.87E+12	0.00E+00	9.54E+13	-0.014	-5.243	0.000
4	DISK	394	8.94E+13	2.95E+12	1.20E+12	4.66E+12	0.00E+00	9.36E+13	-1.370	-5.061	0.000
4	DISK	395	8.17E+13	3.22E+12	1.05E+12	4.22E+12	0.00E+00	8.59E+13	-2.633	-4.534	0.000
4	DISK	396	7.75E+13	3.49E+12	1.08E+12	4.00E+12	0.00E+00	8.21E+13	-3.717	-3.698	0.000
4	DISK	397	8.20E+13	3.78E+12	1.18E+12	4.31E+12	0.00E+00	8.69E+13	-4.547	-2.610	0.000
4	DISK	398	8.95E+13	2.97E+12	1.21E+12	4.67E+12	0.00E+00	9.37E+13	-5.068	-1.344	0.000
4	DISK	399	9.17E+13	2.50E+12	1.51E+12	4.79E+12	0.00E+00	9.57E+13	-5.243	0.014	0.000
4	DISK	400	8.94E+13	2.77E+12	1.34E+12	4.71E+12	0.00E+00	9.36E+13	-5.061	1.370	0.000
4	DISK	401	8.17E+13	3.07E+12	1.36E+12	4.33E+12	0.00E+00	8.61E+13	-4.534	2.633	0.000
4	DISK	402	7.75E+13	3.45E+12	1.75E+12	4.11E+12	0.00E+00	8.27E+13	-3.698	3.717	0.000
4	DISK	403	8.20E+13	3.46E+12	1.65E+12	4.41E+12	0.00E+00	8.71E+13	-2.610	4.547	0.000
4	DISK	404	8.95E+13	3.06E+12	1.31E+12	4.73E+12	0.00E+00	9.39E+13	-1.344	5.068	0.000
4	DISK	405	9.17E+13	2.78E+12	1.22E+12	4.79E+12	0.00E+00	9.58E+13	0.014	5.243	0.000
4	DISK	406	8.94E+13	3.02E+12	1.34E+12	4.67E+12	0.00E+00	9.38E+13	1.370	5.061	0.000
4	DISK	407	8.17E+13	3.35E+12	1.22E+12	4.25E+12	0.00E+00	8.62E+13	2.633	4.534	0.000
4	DISK	408	7.75E+13	3.29E+12	1.11E+12	4.04E+12	0.00E+00	8.19E+13	3.717	3.698	0.000
4	DISK	409	8.20E+13	3.27E+12	1.20E+12	4.26E+12	0.00E+00	8.64E+13	4.547	2.610	0.000
4	DISK	410	8.95E+13	3.03E+12	1.14E+12	4.67E+12	0.00E+00	9.37E+13	5.068	1.344	0.000
4	DISK	411	9.16E+13	2.52E+12	1.07E+12	4.77E+12	0.00E+00	9.52E+13	5.243	0.014	0.000
4	DISK	412	7.09E+13	4.29E+12	2.32E+12	3.92E+12	0.00E+00	7.76E+13	4.493	-0.012	0.000
4	DISK	413	6.77E+13	5.16E+12	2.37E+12	3.68E+12	0.00E+00	7.52E+13	4.337	-1.174	0.000
4	DISK	414	6.05E+13	6.26E+12	2.00E+12	3.46E+12	0.00E+00	6.88E+13	3.885	-2.257	0.000
4	DISK	415	5.76E+13	6.48E+12	2.05E+12	3.46E+12	0.00E+00	6.62E+13	3.169	-3.185	0.000
4	DISK	416	6.07E+13	6.37E+12	1.92E+12	3.48E+12	0.00E+00	6.90E+13	2.236	-3.897	0.000
4	DISK	417	6.78E+13	4.96E+12	1.68E+12	3.61E+12	0.00E+00	7.45E+13	1.152	-4.343	0.000
4	DISK	418	7.12E+13	4.20E+12	1.89E+12	3.87E+12	0.00E+00	7.73E+13	-0.012	-4.493	0.000
4	DISK	419	6.77E+13	5.39E+12	1.88E+12	3.64E+12	0.00E+00	7.50E+13	-1.174	-4.337	0.000
4	DISK	420	6.05E+13	6.05E+12	2.06E+12	3.30E+12	0.00E+00	6.87E+13	-2.257	-3.885	0.000

4	DISK	421	5.76E+13	6.33E+12	2.12E+12	3.26E+12	0.00E+00	6.61E+13	-3.185	-3.169	0.000
4	DISK	422	6.07E+13	6.54E+12	2.00E+12	3.46E+12	0.00E+00	6.92E+13	-3.897	-2.236	0.000
4	DISK	423	6.78E+13	5.34E+12	1.92E+12	3.67E+12	0.00E+00	7.51E+13	-4.343	-1.152	0.000
4	DISK	424	7.12E+13	4.43E+12	2.01E+12	3.95E+12	0.00E+00	7.76E+13	-4.493	0.012	0.000
4	DISK	425	6.77E+13	4.82E+12	1.94E+12	3.76E+12	0.00E+00	7.44E+13	-4.337	1.174	0.000
4	DISK	426	6.05E+13	5.91E+12	1.77E+12	3.47E+12	0.00E+00	6.82E+13	-3.885	2.257	0.000
4	DISK	427	5.76E+13	6.52E+12	2.07E+12	3.34E+12	0.00E+00	6.62E+13	-3.169	3.185	0.000
4	DISK	428	6.07E+13	6.21E+12	1.96E+12	3.32E+12	0.00E+00	6.89E+13	-2.236	3.897	0.000
4	DISK	429	6.78E+13	5.13E+12	1.56E+12	3.60E+12	0.00E+00	7.45E+13	-1.152	4.343	0.000
4	DISK	430	7.12E+13	4.20E+12	1.73E+12	3.87E+12	0.00E+00	7.71E+13	0.012	4.493	0.000
4	DISK	431	6.77E+13	5.35E+12	1.88E+12	3.73E+12	0.00E+00	7.49E+13	1.174	4.337	0.000
4	DISK	432	6.05E+13	6.52E+12	1.48E+12	3.40E+12	0.00E+00	6.85E+13	2.257	3.885	0.000
4	DISK	433	5.76E+13	6.52E+12	1.35E+12	3.20E+12	0.00E+00	6.55E+13	3.185	3.169	0.000
4	DISK	434	6.07E+13	6.23E+12	1.76E+12	3.27E+12	0.00E+00	6.87E+13	3.897	2.236	0.000
4	DISK	435	6.78E+13	5.25E+12	1.77E+12	3.70E+12	0.00E+00	7.49E+13	4.343	1.152	0.000
4	DISK	436	7.09E+13	4.39E+12	1.74E+12	3.95E+12	0.00E+00	7.71E+13	4.493	0.012	0.000
4	DISK	437	5.09E+13	8.29E+12	4.36E+12	3.22E+12	0.00E+00	6.35E+13	3.743	-0.010	0.000
4	DISK	438	4.87E+13	1.04E+13	4.43E+12	3.30E+12	0.00E+00	6.35E+13	3.613	-0.978	0.000
4	DISK	439	3.96E+13	1.18E+13	3.59E+12	2.87E+12	0.00E+00	5.50E+13	3.237	-1.880	0.000
4	DISK	440	3.35E+13	1.17E+13	3.34E+12	2.32E+12	0.00E+00	4.85E+13	2.640	-2.654	0.000
4	DISK	441	3.99E+13	1.16E+13	3.59E+12	2.52E+12	0.00E+00	5.51E+13	1.863	-3.247	0.000
4	DISK	442	4.88E+13	9.82E+12	4.07E+12	2.91E+12	0.00E+00	6.27E+13	0.959	-3.618	0.000
4	DISK	443	5.12E+13	8.90E+12	4.21E+12	3.04E+12	0.00E+00	6.43E+13	-0.010	-3.743	0.000
4	DISK	444	4.87E+13	9.96E+12	3.78E+12	3.03E+12	0.00E+00	6.25E+13	-0.978	-3.613	0.000
4	DISK	445	3.96E+13	1.10E+13	4.06E+12	2.65E+12	0.00E+00	5.46E+13	-1.880	-3.237	0.000
4	DISK	446	3.35E+13	1.24E+13	4.24E+12	2.47E+12	0.00E+00	5.02E+13	-2.654	-2.640	0.000
4	DISK	447	3.99E+13	1.21E+13	3.97E+12	2.76E+12	0.00E+00	5.60E+13	-3.247	-1.863	0.000
4	DISK	448	4.88E+13	9.51E+12	4.50E+12	3.21E+12	0.00E+00	6.29E+13	-3.618	-0.959	0.000
4	DISK	449	5.12E+13	7.83E+12	4.13E+12	3.26E+12	0.00E+00	6.31E+13	-3.743	0.010	0.000
4	DISK	450	4.87E+13	8.52E+12	3.55E+12	2.95E+12	0.00E+00	6.08E+13	-3.613	0.978	0.000
4	DISK	451	3.96E+13	1.11E+13	3.64E+12	2.83E+12	0.00E+00	5.43E+13	-3.237	1.880	0.000
4	DISK	452	3.35E+13	1.20E+13	3.68E+12	2.56E+12	0.00E+00	4.92E+13	-2.640	2.654	0.000
4	DISK	453	3.99E+13	1.14E+13	3.95E+12	2.78E+12	0.00E+00	5.52E+13	-1.863	3.247	0.000
4	DISK	454	4.88E+13	1.04E+13	3.74E+12	3.20E+12	0.00E+00	6.30E+13	-0.959	3.618	0.000
4	DISK	455	5.12E+13	8.89E+12	3.77E+12	3.23E+12	0.00E+00	6.38E+13	0.010	3.743	0.000
4	DISK	456	4.87E+13	9.93E+12	3.93E+12	3.23E+12	0.00E+00	6.26E+13	0.978	3.613	0.000
4	DISK	457	3.96E+13	1.20E+13	3.49E+12	2.71E+12	0.00E+00	5.51E+13	1.880	3.237	0.000
4	DISK	458	3.35E+13	1.21E+13	3.40E+12	2.32E+12	0.00E+00	4.90E+13	2.654	2.640	0.000
4	DISK	459	3.99E+13	1.12E+13	3.65E+12	2.53E+12	0.00E+00	5.48E+13	3.247	1.863	0.000
4	DISK	460	4.88E+13	9.45E+12	3.60E+12	2.86E+12	0.00E+00	6.19E+13	3.618	0.959	0.000
4	DISK	461	5.09E+13	8.29E+12	3.71E+12	3.10E+12	0.00E+00	6.29E+13	3.743	0.010	0.000
4	DISK	462	4.07E+13	1.09E+13	4.87E+12	2.87E+12	0.00E+00	5.66E+13	3.008	-0.008	0.000
4	DISK	463	3.89E+13	1.38E+13	5.01E+12	3.25E+12	0.00E+00	5.77E+13	2.904	-0.786	0.000
4	DISK	464	2.86E+13	1.53E+13	4.69E+12	2.71E+12	0.00E+00	4.86E+13	2.601	-1.511	0.000
4	DISK	465	2.14E+13	1.45E+13	4.39E+12	1.71E+12	0.00E+00	4.02E+13	2.122	-2.133	0.000
4	DISK	466	2.90E+13	1.46E+13	4.87E+12	2.01E+12	0.00E+00	4.85E+13	1.497	-2.609	0.000
4	DISK	467	3.90E+13	1.28E+13	6.01E+12	2.69E+12	0.00E+00	5.79E+13	0.771	-2.908	0.000
4	DISK	468	4.10E+13	1.21E+13	5.83E+12	2.82E+12	0.00E+00	5.90E+13	-0.008	-3.008	0.000
4	DISK	469	3.89E+13	1.28E+13	5.06E+12	2.85E+12	0.00E+00	5.68E+13	-0.786	-2.904	0.000
4	DISK	470	2.86E+13	1.39E+13	5.11E+12	2.40E+12	0.00E+00	4.77E+13	-1.511	-2.601	0.000
4	DISK	471	2.14E+13	1.65E+13	5.39E+12	2.05E+12	0.00E+00	4.33E+13	-2.133	-2.122	0.000
4	DISK	472	2.90E+13	1.61E+13	5.19E+12	2.36E+12	0.00E+00	5.03E+13	-2.609	-1.497	0.000
4	DISK	473	3.90E+13	1.22E+13	6.38E+12	3.11E+12	0.00E+00	5.76E+13	-2.908	-0.771	0.000
4	DISK	474	4.10E+13	9.80E+12	6.04E+12	3.09E+12	0.00E+00	5.69E+13	-3.008	0.008	0.000
4	DISK	475	3.89E+13	1.08E+13	4.92E+12	2.72E+12	0.00E+00	5.46E+13	-2.904	0.786	0.000
4	DISK	476	2.86E+13	1.43E+13	5.17E+12	2.65E+12	0.00E+00	4.81E+13	-2.601	1.511	0.000
4	DISK	477	2.14E+13	1.58E+13	5.09E+12	2.26E+12	0.00E+00	4.23E+13	-2.122	2.133	0.000
4	DISK	478	2.90E+13	1.49E+13	5.69E+12	2.67E+12	0.00E+00	4.97E+13	-1.497	2.609	0.000
4	DISK	479	3.90E+13	1.43E+13	5.29E+12	3.16E+12	0.00E+00	5.86E+13	-0.771	2.908	0.000
4	DISK	480	4.10E+13	1.26E+13	5.25E+12	3.14E+12	0.00E+00	5.88E+13	0.008	3.008	0.000
4	DISK	481	3.89E+13	1.28E+13	5.65E+12	3.05E+12	0.00E+00	5.73E+13	0.786	2.904	0.000
4	DISK	482	2.86E+13	1.54E+13	4.94E+12	2.32E+12	0.00E+00	4.90E+13	1.511	2.601	0.000
4	DISK	483	2.14E+13	1.55E+13	4.80E+12	1.97E+12	0.00E+00	4.17E+13	2.133	2.122	0.000
4	DISK	484	2.90E+13	1.43E+13	4.96E+12	2.40E+12	0.00E+00	4.83E+13	2.609	1.497	0.000
4	DISK	485	3.90E+13	1.24E+13	4.76E+12	2.58E+12	0.00E+00	5.62E+13	2.908	0.771	0.000
4	DISK	486	4.07E+13	1.10E+13	4.76E+12	2.66E+12	0.00E+00	5.65E+13	3.008	0.008	0.000
5	SPHERE	487	7.00E-13	1.50E+12	5.36E+12	0.00E+00	5.45E+11	6.86E+12	0.204	0.001	14.992
5	SPHERE	488	6.14E-13	1.62E+12	5.98E+12	0.00E+00	5.58E+11	7.60E+12	0.197	0.053	14.992
5	SPHERE	489	4.53E-13	1.67E+12	5.93E+12	0.00E+00	5.12E+11	7.60E+12	0.176	0.102	14.992
5	SPHERE	490	3.92E-13	1.38E+12	5.41E+12	0.00E+00	3.97E+11	6.79E+12	0.144	0.145	14.992
5	SPHERE	491	4.56E-13	1.28E+12	5.56E+12	0.00E+00	3.34E+11	6.84E+12	0.102	0.177	14.992
5	SPHERE	492	6.17E-13	1.39E+12	5.74E+12	0.00E+00	4.09E+11	7.13E+12	0.052	0.197	14.992
5	SPHERE	493	7.22E-13	1.40E+12	5.43E+12	0.00E+00	3.80E+11	6.83E+12	-0.001	0.204	14.992
5	SPHERE	494	6.14E-13	1.60E+12	5.27E+12	0.00E+00	3.20E+11	6.86E+12	-0.053	0.197	14.992
5	SPHERE	495	4.53E-13	1.37E+12	5.45E+12	0.00E+00	3.36E+11	6.82E+12	-0.102	0.176	14.992
5	SPHERE	496	3.92E-13	1.53E+12	5.87E+12	0.00E+00	3.01E+11	7.40E+12	-0.145	0.144	14.992
5	SPHERE	497	4.56E-13	1.35E+12	6.27E+12	0.00E+00	3.17E+11	7.62E+12	-0.177	0.102	14.992
5	SPHERE	498	6.17E-13	9.54E+11	5.97E+12	0.00E+00	2.96E+11	6.92E+12	-0.197	0.052	14.992
5	SPHERE	499	7.22E-13	1.09E+12	5.73E+12	0.00E+00	2.38E+11	6.82E+12	-0.204	-0.001	14.992
5	SPHERE	500	6.14E-13	1.06E+12	5.46E+12	0.00E+00	2.06E+11	6.52E+12	-0.197	-0.053	14.992
5	SPHERE	501	4.53E-13	1.10E+12	5.66E+12	0.00E+00	1.81E+11	6.76E+12	-0.176	-0.102	14.992
5	SPHERE	502	3.92E-13	1.35E+12	5.96E+12	0.00E+00	2.38E+11	7.31E+12	-0.144	-0.145	14.992
5	SPHERE	503	4.56E-13	1.05E+12	5.08E+12	0.00E+00	4.19E+11	6.13E+12	-0.102	-0.177	14.992
5	SPHERE	504	6.17E-13	7.61E+11	5.03E+12	0.00E+00	4.57E+11	5.79E+12	-0.052	-0.197	14.992
5	SPHERE	505	7.22E-13	9.08E+11	5.61E+12	0.00E+00	3.29E+11	6.52E+12	0.001	-0.204	14.992
5	SPHERE	506	6.14E-13	8.46E+11	5.28E+12	0.00E+00	1.53E+11	6.13E+12	0.053	-0.197	14.992
5	SPHERE	507	4.53E-13	1.05E+12	5.08E+12	0.00E+00	1.13E+11	6.12E+12	0.102	-0.176	14.992
5	SPHERE	508	3.92E-13	8.34E+11	5.27E+12	0.00E+00	2.49E+11	6.10E+12	0.145	-0.144	14.992
5	SPHERE	509	4.56E-13	1.03E+12	5.63E+12	0.00E+00	2.93E+11	6.66E+12	0.177	-0.102	14.992
5	SPHERE	510	6.17E-13	1.39E+12	5.56E+12	0.00E+00	1.97E+11	6.95E+12	0.197	-0.052	14.992
5	SPHERE	511	7.00E-13	1.29E+12	5.32E+12	0.00E+00	1.98E+11	6.61E+12	0.204	-0.001	14.992
5	SPHERE	512	1.14E-05	3.16E+12	5.97E+12	0.00E+00	5.85E+11	9.13E+12	1.871	0.005	14.158

5	SPHERE	513	6.10E-06	2.93E+12	6.30E+12	0.00E+00	4.49E+11	9.23E+12	1.806	0.489	14.158
5	SPHERE	514	3.42E-07	2.74E+12	6.19E+12	0.00E+00	4.71E+11	8.93E+12	1.618	0.940	14.158
5	SPHERE	515	3.92E-13	2.42E+12	6.14E+12	0.00E+00	4.67E+11	8.56E+12	1.319	1.326	14.158
5	SPHERE	516	3.54E-07	2.46E+12	6.28E+12	0.00E+00	4.65E+11	8.74E+12	0.931	1.623	14.158
5	SPHERE	517	6.35E-06	2.49E+12	6.29E+12	0.00E+00	4.76E+11	8.78E+12	0.479	1.808	14.158
5	SPHERE	518	1.27E-05	2.58E+12	5.86E+12	0.00E+00	3.75E+11	8.44E+12	-0.005	1.871	14.158
5	SPHERE	519	6.10E-06	3.02E+12	5.78E+12	0.00E+00	3.79E+11	8.80E+12	-0.489	1.806	14.158
5	SPHERE	520	3.42E-07	2.59E+12	6.04E+12	0.00E+00	5.04E+11	8.63E+12	-0.940	1.618	14.158
5	SPHERE	521	3.92E-13	2.46E+12	5.97E+12	0.00E+00	3.91E+11	8.43E+12	-1.326	1.319	14.158
5	SPHERE	522	3.54E-07	2.59E+12	6.41E+12	0.00E+00	4.11E+11	9.00E+12	-1.623	0.931	14.158
5	SPHERE	523	6.35E-06	2.53E+12	6.30E+12	0.00E+00	4.33E+11	8.83E+12	-1.808	0.479	14.158
5	SPHERE	524	1.27E-05	2.60E+12	6.02E+12	0.00E+00	2.90E+11	8.63E+12	-1.871	-0.005	14.158
5	SPHERE	525	6.10E-06	2.29E+12	6.01E+12	0.00E+00	3.62E+11	8.30E+12	-1.806	-0.489	14.158
5	SPHERE	526	3.42E-07	2.14E+12	6.45E+12	0.00E+00	3.72E+11	8.59E+12	-1.618	-0.940	14.158
5	SPHERE	527	3.92E-13	2.57E+12	6.29E+12	0.00E+00	3.59E+11	8.86E+12	-1.319	-1.326	14.158
5	SPHERE	528	3.54E-07	2.25E+12	5.76E+12	0.00E+00	4.78E+11	8.01E+12	-0.931	-1.623	14.158
5	SPHERE	529	6.35E-06	1.98E+12	6.04E+12	0.00E+00	5.35E+11	8.02E+12	-0.479	-1.808	14.158
5	SPHERE	530	1.27E-05	2.35E+12	5.89E+12	0.00E+00	4.90E+11	8.23E+12	0.005	-1.871	14.158
5	SPHERE	531	6.10E-06	2.32E+12	5.66E+12	0.00E+00	4.01E+11	7.98E+12	0.489	-1.806	14.158
5	SPHERE	532	3.42E-07	2.68E+12	5.73E+12	0.00E+00	3.23E+11	8.41E+12	0.940	-1.618	14.158
5	SPHERE	533	3.92E-13	2.60E+12	6.34E+12	0.00E+00	3.77E+11	8.94E+12	1.326	-1.319	14.158
5	SPHERE	534	3.54E-07	2.43E+12	6.76E+12	0.00E+00	4.45E+11	9.20E+12	1.623	-0.931	14.158
5	SPHERE	535	6.35E-06	2.93E+12	6.26E+12	0.00E+00	4.63E+11	9.18E+12	1.808	-0.479	14.158
5	SPHERE	536	1.14E-05	3.10E+12	5.95E+12	0.00E+00	4.83E+11	9.05E+12	1.871	-0.005	14.158
5	SPHERE	537	1.42E+03	4.09E+12	3.89E+12	0.00E+00	4.67E+11	7.98E+12	2.360	0.006	13.325
5	SPHERE	538	7.48E+02	3.60E+12	4.21E+12	0.00E+00	3.11E+11	7.81E+12	2.278	0.617	13.325
5	SPHERE	539	3.57E+01	3.51E+12	4.37E+12	0.00E+00	4.30E+11	7.88E+12	2.041	1.185	13.325
5	SPHERE	540	3.92E-13	3.47E+12	4.65E+12	0.00E+00	5.37E+11	8.12E+12	1.664	1.673	13.325
5	SPHERE	541	3.73E+01	3.66E+12	4.59E+12	0.00E+00	5.20E+11	8.25E+12	1.175	2.047	13.325
5	SPHERE	542	7.80E+02	3.54E+12	4.22E+12	0.00E+00	4.23E+11	7.76E+12	0.605	2.281	13.325
5	SPHERE	543	1.59E+03	3.56E+12	3.89E+12	0.00E+00	2.84E+11	7.45E+12	-0.006	2.360	13.325
5	SPHERE	544	7.48E+02	3.89E+12	4.09E+12	0.00E+00	2.85E+11	7.98E+12	-0.617	2.278	13.325
5	SPHERE	545	3.57E+01	3.44E+12	4.49E+12	0.00E+00	3.69E+11	7.93E+12	-1.185	2.041	13.325
5	SPHERE	546	3.92E-13	3.16E+12	4.33E+12	0.00E+00	3.93E+11	7.49E+12	-1.673	1.664	13.325
5	SPHERE	547	3.73E+01	3.35E+12	4.36E+12	0.00E+00	4.06E+11	7.72E+12	-2.047	1.175	13.325
5	SPHERE	548	7.80E+02	3.94E+12	4.31E+12	0.00E+00	4.53E+11	8.25E+12	-2.281	0.605	13.325
5	SPHERE	549	1.59E+03	4.26E+12	3.98E+12	0.00E+00	3.90E+11	8.23E+12	-2.360	-0.006	13.325
5	SPHERE	550	7.48E+02	3.49E+12	4.41E+12	0.00E+00	3.91E+11	7.90E+12	-2.278	-0.617	13.325
5	SPHERE	551	3.57E+01	3.07E+12	5.19E+12	0.00E+00	4.56E+11	8.26E+12	-2.041	-1.185	13.325
5	SPHERE	552	3.92E-13	3.36E+12	4.57E+12	0.00E+00	4.82E+11	7.94E+12	-1.664	-1.673	13.325
5	SPHERE	553	3.73E+01	3.16E+12	4.19E+12	0.00E+00	4.79E+11	7.35E+12	-1.175	-2.047	13.325
5	SPHERE	554	7.80E+02	3.34E+12	4.29E+12	0.00E+00	4.32E+11	7.63E+12	-0.605	-2.281	13.325
5	SPHERE	555	1.59E+03	4.02E+12	3.80E+12	0.00E+00	4.51E+11	7.81E+12	0.006	-2.360	13.325
5	SPHERE	556	7.48E+02	3.68E+12	4.17E+12	0.00E+00	4.68E+11	7.85E+12	0.617	-2.278	13.325
5	SPHERE	557	3.57E+01	3.43E+12	4.52E+12	0.00E+00	3.88E+11	7.95E+12	1.185	-2.041	13.325
5	SPHERE	558	3.92E-13	3.41E+12	4.85E+12	0.00E+00	4.62E+11	8.27E+12	1.673	-1.664	13.325
5	SPHERE	559	3.73E+01	3.44E+12	5.01E+12	0.00E+00	5.81E+11	8.45E+12	2.047	-1.175	13.325
5	SPHERE	560	7.80E+02	4.00E+12	4.26E+12	0.00E+00	5.60E+11	8.25E+12	2.281	-0.605	13.325
5	SPHERE	561	1.42E+03	4.19E+12	3.89E+12	0.00E+00	5.28E+11	8.08E+12	2.360	-0.006	13.325
5	SPHERE	562	2.45E+06	4.68E+12	8.43E+11	0.00E+00	2.61E+11	5.52E+12	2.500	0.007	12.492
5	SPHERE	563	1.66E+06	4.34E+12	1.01E+12	0.00E+00	2.27E+11	5.36E+12	2.413	0.653	12.492
5	SPHERE	564	3.81E+05	4.28E+12	1.06E+12	0.00E+00	3.13E+11	5.34E+12	2.162	1.256	12.492
5	SPHERE	565	7.75E+03	4.29E+12	1.24E+12	0.00E+00	3.60E+11	5.53E+12	1.763	1.772	12.492
5	SPHERE	566	4.00E+05	4.26E+12	1.35E+12	0.00E+00	2.94E+11	5.60E+12	1.244	2.168	12.492
5	SPHERE	567	1.70E+06	4.27E+12	1.04E+12	0.00E+00	2.57E+11	5.32E+12	0.641	2.416	12.492
5	SPHERE	568	2.45E+06	4.07E+12	1.01E+12	0.00E+00	2.63E+11	5.08E+12	-0.007	2.500	12.492
5	SPHERE	569	1.66E+06	4.09E+12	1.12E+12	0.00E+00	2.17E+11	5.22E+12	-0.653	2.413	12.492
5	SPHERE	570	3.81E+05	4.13E+12	1.38E+12	0.00E+00	1.61E+11	5.50E+12	-1.256	2.162	12.492
5	SPHERE	571	7.75E+03	3.71E+12	1.50E+12	0.00E+00	2.38E+11	5.21E+12	-1.772	1.763	12.492
5	SPHERE	572	4.00E+05	3.71E+12	1.23E+12	0.00E+00	2.93E+11	4.94E+12	-2.168	1.244	12.492
5	SPHERE	573	1.70E+06	4.31E+12	1.13E+12	0.00E+00	3.43E+11	5.44E+12	-2.416	0.641	12.492
5	SPHERE	574	2.45E+06	4.37E+12	9.37E+11	0.00E+00	3.43E+11	5.30E+12	-2.500	-0.007	12.492
5	SPHERE	575	1.66E+06	4.00E+12	1.19E+12	0.00E+00	2.19E+11	5.19E+12	-2.413	-0.653	12.492
5	SPHERE	576	3.81E+05	3.82E+12	1.69E+12	0.00E+00	2.74E+11	5.51E+12	-2.162	-1.256	12.492
5	SPHERE	577	7.75E+03	3.90E+12	1.41E+12	0.00E+00	3.54E+11	5.32E+12	-1.763	-1.772	12.492
5	SPHERE	578	4.00E+05	3.96E+12	1.14E+12	0.00E+00	3.05E+11	5.10E+12	-1.244	-2.168	12.492
5	SPHERE	579	1.70E+06	4.11E+12	8.97E+11	0.00E+00	2.04E+11	5.00E+12	-0.641	-2.416	12.492
5	SPHERE	580	2.45E+06	4.46E+12	8.14E+11	0.00E+00	2.30E+11	5.27E+12	0.007	-2.500	12.492
5	SPHERE	581	1.66E+06	4.20E+12	1.22E+12	0.00E+00	2.48E+11	5.43E+12	0.653	-2.413	12.492
5	SPHERE	582	3.81E+05	3.41E+12	1.48E+12	0.00E+00	2.54E+11	4.90E+12	1.256	-2.162	12.492
5	SPHERE	583	7.75E+03	3.11E+12	1.31E+12	0.00E+00	3.81E+11	4.42E+12	1.772	-1.763	12.492
5	SPHERE	584	4.00E+05	4.01E+12	1.11E+12	0.00E+00	4.27E+11	5.12E+12	2.168	-1.244	12.492
5	SPHERE	585	1.70E+06	4.59E+12	8.11E+11	0.00E+00	3.93E+11	5.40E+12	2.416	-0.641	12.492
5	SPHERE	586	2.45E+06	4.57E+12	6.80E+11	0.00E+00	3.64E+11	5.25E+12	2.500	-0.007	12.492
5	SPHERE	587	2.32E+06	5.43E+12	2.76E+11	0.00E+00	2.97E+11	5.70E+12	2.354	0.006	11.658
5	SPHERE	588	1.58E+06	5.12E+12	3.69E+11	0.00E+00	2.24E+11	5.49E+12	2.272	0.615	11.658
5	SPHERE	589	3.71E+05	4.95E+12	3.22E+11	0.00E+00	1.82E+11	5.27E+12	2.036	1.182	11.658
5	SPHERE	590	7.82E+03	4.81E+12	2.58E+11	0.00E+00	2.29E+11	5.07E+12	1.660	1.669	11.658
5	SPHERE	591	3.90E+05	4.49E+12	4.77E+11	0.00E+00	2.07E+11	4.97E+12	1.172	2.042	11.658
5	SPHERE	592	1.62E+06	4.78E+12	4.11E+11	0.00E+00	2.59E+11	5.19E+12	0.603	2.275	11.658
5	SPHERE	593	2.32E+06	5.04E+12	3.08E+11	0.00E+00	3.50E+11	5.34E+12	-0.006	2.354	11.658
5	SPHERE	594	1.58E+06	4.84E+12	4.82E+11	0.00E+00	2.74E+11	5.32E+12	-0.615	2.272	11.658
5	SPHERE	595	3.71E+05	4.78E+12	3.76E+11	0.00E+00	2.16E+11	5.16E+12	-1.182	2.036	11.658
5	SPHERE	596	7.82E+03	4.64E+12	3.29E+11	0.00E+00	3.02E+11	4.97E+12	-1.669	1.660	11.658
5	SPHERE	597	3.90E+05	4.65E+12	4.58E+11	0.00E+00	3.40E+11	5.11E+12	-2.042	1.172	11.658
5	SPHERE	598	1.62E+06	4.74E+12	3.26E+11	0.00E+00	3.13E+11	5.07E+12	-2.275	0.603	11.658
5	SPHERE	599	2.32E+06	4.82E+12	3.51E+11	0.00E+00	2.82E+11	5.17E+12	-2.354	-0.006	11.658
5	SPHERE	600	1.58E+06	4.78E+12	4.38E+11	0.00E+00	1.86E+11	5.22E+12	-2.272	-0.615	11.658
5	SPHERE	601	3.71E+05	4.54E+12	2.91E+11	0.00E+00	1.68E+11	4.83E+12	-2.036	-1.182	11.658
5	SPHERE	602	7.82E+03	4.77E+12	3.19E+11	0.00E+00	2.45E+11	5.09E+12	-1.660	-1.669	11.658
5	SPHERE	603	3.90E+05	4.84E+12	2.79E+11	0.00E+00	2.57E+11	5.12E+12	-1.172	-2.042	11.658
5	SPHERE	604	1.62E+06	4.65E+12	4.28E+11	0.00E+00	2.60E+11	5.08E+12	-0.603	-2.275	11.658

5	SPHERE	605	2.32E+06	4.96E+12	5.19E+11	0.00E+00	3.59E+11	5.48E+12	0.006	-2.354	11.658
5	SPHERE	606	1.58E+06	4.92E+12	4.52E+11	0.00E+00	3.36E+11	5.38E+12	0.615	-2.272	11.658
5	SPHERE	607	3.71E+05	4.73E+12	3.36E+11	0.00E+00	2.15E+11	5.07E+12	1.182	-2.036	11.658
5	SPHERE	608	7.82E+03	4.81E+12	2.29E+11	0.00E+00	2.98E+11	5.04E+12	1.669	-1.660	11.658
5	SPHERE	609	3.90E+05	5.01E+12	3.38E+11	0.00E+00	3.00E+11	5.34E+12	2.042	-1.172	11.658
5	SPHERE	610	1.62E+06	5.26E+12	3.18E+11	0.00E+00	2.55E+11	5.58E+12	2.275	-0.603	11.658
5	SPHERE	611	2.32E+06	5.30E+12	1.71E+11	0.00E+00	3.23E+11	5.47E+12	2.354	-0.006	11.658
5	SPHERE	612	1.17E+04	2.61E+12	3.70E+11	0.00E+00	1.81E+11	2.98E+12	1.856	0.005	10.825
5	SPHERE	613	1.11E+04	2.43E+12	5.77E+11	0.00E+00	1.47E+11	3.01E+12	1.791	0.485	10.825
5	SPHERE	614	5.54E+03	2.55E+12	5.76E+11	0.00E+00	9.93E+10	3.12E+12	1.605	0.932	10.825
5	SPHERE	615	2.38E+02	2.48E+12	4.40E+11	0.00E+00	1.30E+11	2.92E+12	1.309	1.316	10.825
5	SPHERE	616	5.76E+03	2.18E+12	4.94E+11	0.00E+00	1.27E+11	2.68E+12	0.924	1.610	10.825
5	SPHERE	617	1.12E+04	2.41E+12	4.98E+11	0.00E+00	1.65E+11	2.91E+12	0.476	1.794	10.825
5	SPHERE	618	1.18E+04	2.80E+12	3.88E+11	0.00E+00	2.15E+11	3.19E+12	-0.005	1.856	10.825
5	SPHERE	619	1.11E+04	2.65E+12	4.16E+11	0.00E+00	1.35E+11	3.07E+12	-0.485	1.791	10.825
5	SPHERE	620	5.54E+03	2.39E+12	4.18E+11	0.00E+00	9.36E+10	2.80E+12	-0.932	1.605	10.825
5	SPHERE	621	2.38E+02	2.49E+12	4.91E+11	0.00E+00	2.10E+11	2.98E+12	-1.316	1.309	10.825
5	SPHERE	622	5.76E+03	2.48E+12	6.14E+11	0.00E+00	1.98E+11	3.09E+12	-1.610	0.924	10.825
5	SPHERE	623	1.12E+04	2.52E+12	5.96E+11	0.00E+00	2.02E+11	3.12E+12	-1.794	0.476	10.825
5	SPHERE	624	1.18E+04	2.85E+12	6.21E+11	0.00E+00	2.03E+11	3.47E+12	-1.856	-0.005	10.825
5	SPHERE	625	1.11E+04	2.67E+12	4.90E+11	0.00E+00	1.11E+11	3.16E+12	-1.791	-0.485	10.825
5	SPHERE	626	5.54E+03	2.39E+12	3.31E+11	0.00E+00	8.89E+10	2.72E+12	-1.605	-0.932	10.825
5	SPHERE	627	2.38E+02	2.56E+12	3.95E+11	0.00E+00	1.32E+11	2.95E+12	-1.309	-1.316	10.825
5	SPHERE	628	5.76E+03	2.54E+12	4.48E+11	0.00E+00	1.64E+11	2.98E+12	-0.924	-1.610	10.825
5	SPHERE	629	1.12E+04	2.50E+12	5.16E+11	0.00E+00	1.81E+11	3.01E+12	-0.476	-1.794	10.825
5	SPHERE	630	1.18E+04	2.84E+12	5.79E+11	0.00E+00	2.54E+11	3.42E+12	0.005	-1.856	10.825
5	SPHERE	631	1.11E+04	2.67E+12	5.61E+11	0.00E+00	2.55E+11	3.23E+12	0.485	-1.791	10.825
5	SPHERE	632	5.54E+03	2.73E+12	4.97E+11	0.00E+00	1.24E+11	3.23E+12	0.932	-1.605	10.825
5	SPHERE	633	2.38E+02	3.06E+12	3.77E+11	0.00E+00	1.35E+11	3.44E+12	1.316	-1.309	10.825
5	SPHERE	634	5.76E+03	2.72E+12	5.31E+11	0.00E+00	1.62E+11	3.25E+12	1.610	-0.924	10.825
5	SPHERE	635	1.12E+04	2.59E+12	4.95E+11	0.00E+00	7.49E+10	3.09E+12	1.794	-0.476	10.825
5	SPHERE	636	1.17E+04	2.65E+12	3.40E+11	0.00E+00	1.14E+11	2.99E+12	1.856	-0.005	10.825
5	SPHERE	637	1.85E-07	4.41E+11	5.24E+11	0.00E+00	1.12E+10	9.64E+11	0.204	0.001	10.008
5	SPHERE	638	1.85E-07	4.62E+11	7.27E+11	0.00E+00	3.42E+10	1.19E+12	0.197	0.053	10.008
5	SPHERE	639	1.85E-07	6.59E+11	6.22E+11	0.00E+00	4.25E+10	1.28E+12	0.176	0.102	10.008
5	SPHERE	640	1.85E-07	5.61E+11	5.83E+11	0.00E+00	1.67E+10	1.14E+12	0.144	0.145	10.008
5	SPHERE	641	1.85E-07	3.85E+11	5.78E+11	0.00E+00	1.56E+10	9.62E+11	0.102	0.177	10.008
5	SPHERE	642	1.85E-07	4.54E+11	6.10E+11	0.00E+00	4.87E+10	1.06E+12	0.052	0.197	10.008
5	SPHERE	643	1.85E-07	4.81E+11	5.69E+11	0.00E+00	6.95E+10	1.05E+12	-0.001	0.204	10.008
5	SPHERE	644	1.85E-07	5.43E+11	4.04E+11	0.00E+00	3.33E+10	9.47E+11	-0.053	0.197	10.008
5	SPHERE	645	1.85E-07	4.98E+11	5.42E+11	0.00E+00	5.68E+09	1.04E+12	-0.102	0.176	10.008
5	SPHERE	646	1.85E-07	3.41E+11	7.70E+11	0.00E+00	1.10E+10	1.11E+12	-0.145	0.144	10.008
5	SPHERE	647	1.85E-07	3.13E+11	7.38E+11	0.00E+00	1.92E+10	1.05E+12	-0.177	0.102	10.008
5	SPHERE	648	1.85E-07	4.98E+11	8.43E+11	0.00E+00	1.27E+11	1.34E+12	-0.197	0.052	10.008
5	SPHERE	649	1.85E-07	5.81E+11	8.17E+11	0.00E+00	1.05E+11	1.40E+12	-0.204	-0.001	10.008
5	SPHERE	650	1.85E-07	4.58E+11	4.93E+11	0.00E+00	3.82E+10	9.51E+11	-0.197	-0.053	10.008
5	SPHERE	651	1.85E-07	4.89E+11	4.27E+11	0.00E+00	3.71E+10	9.16E+11	-0.176	-0.102	10.008
5	SPHERE	652	1.85E-07	5.34E+11	5.44E+11	0.00E+00	2.46E+10	1.08E+12	-0.144	-0.145	10.008
5	SPHERE	653	1.85E-07	5.14E+11	6.65E+11	0.00E+00	3.36E+10	1.18E+12	-0.102	-0.177	10.008
5	SPHERE	654	1.85E-07	5.57E+11	5.38E+11	0.00E+00	2.79E+10	1.09E+12	-0.052	-0.197	10.008
5	SPHERE	655	1.85E-07	5.61E+11	4.94E+11	0.00E+00	2.24E+10	1.06E+12	0.001	-0.204	10.008
5	SPHERE	656	1.85E-07	4.59E+11	6.19E+11	0.00E+00	6.89E+10	1.08E+12	0.053	-0.197	10.008
5	SPHERE	657	1.85E-07	3.81E+11	7.02E+11	0.00E+00	7.54E+10	1.08E+12	0.102	-0.176	10.008
5	SPHERE	658	1.85E-07	4.97E+11	6.11E+11	0.00E+00	1.78E+10	1.11E+12	0.145	-0.144	10.008
5	SPHERE	659	1.85E-07	5.02E+11	6.46E+11	0.00E+00	3.95E+10	1.15E+12	0.177	-0.102	10.008
5	SPHERE	660	1.85E-07	4.09E+11	5.82E+11	0.00E+00	3.22E+10	9.91E+11	0.197	-0.052	10.008
5	SPHERE	661	1.85E-07	4.21E+11	4.67E+11	0.00E+00	6.28E+09	8.88E+11	0.204	-0.001	10.008

1

TITLE="a new file"

SURFACE 1 NUMBER OF NODES 36 NUMBER OF ELEMENTS 25

CONNECTIVITY MATRIX OF NODE NUMBERS

1	2	8	7
2	3	9	8
3	4	10	9
4	5	11	10
5	6	12	11
7	8	14	13
8	9	15	14
9	10	16	15
10	11	17	16
11	12	18	17
13	14	20	19
14	15	21	20
15	16	22	21
16	17	23	22
17	18	24	23
19	20	26	25
20	21	27	26
21	22	28	27

22	23	29	28
23	24	30	29
25	26	32	31
26	27	33	32
27	28	34	33
28	29	35	34
29	30	36	35

SURFACE 2 NUMBER OF NODES 150 NUMBER OF ELEMENTS 125
CONNECTIVITY MATRIX OF NODE NUMBERS

37	38	63	62
38	39	64	63
39	40	65	64
40	41	66	65
41	42	67	66
42	43	68	67
43	44	69	68
44	45	70	69
45	46	71	70
46	47	72	71
47	48	73	72
48	49	74	73
49	50	75	74
50	51	76	75
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62	86	111	87
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88	89	114	113
89	90	115	114

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93	94	119	118
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122	123	148	147
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124	125	150	149
125	126	151	150
126	127	152	151
127	128	153	152
128	129	154	153
129	130	155	154
130	131	156	155
131	132	157	156
132	133	158	157
133	134	159	158
134	135	160	159
135	136	161	160
112	136	161	137
137	138	163	162
138	139	164	163
139	140	165	164
140	141	166	165
141	142	167	166
142	143	168	167
143	144	169	168
144	145	170	169
145	146	171	170
146	147	172	171
147	148	173	172
148	149	174	173
149	150	175	174
150	151	176	175
151	152	177	176
152	153	178	177
153	154	179	178

154	155	180	179
155	156	181	180
156	157	182	181
157	158	183	182
158	159	184	183
159	160	185	184
160	161	186	185
137	161	186	162

SURFACE 3 NUMBER OF NODES 175 NUMBER OF ELEMENTS 150
CONNECTIVITY MATRIX OF NODE NUMBERS

187	188	213	212
188	189	214	213
189	190	215	214
190	191	216	215
191	192	217	216
192	193	218	217
193	194	219	218
194	195	220	219
195	196	221	220
196	197	222	221
197	198	223	222
198	199	224	223
199	200	225	224
200	201	226	225
201	202	227	226
202	203	228	227
203	204	229	228
204	205	230	229
205	206	231	230
206	207	232	231
207	208	233	232
208	209	234	233
209	210	235	234
210	211	236	235
187	211	236	212
212	213	238	237
213	214	239	238
214	215	240	239
215	216	241	240
216	217	242	241
217	218	243	242
218	219	244	243
219	220	245	244
220	221	246	245
221	222	247	246
222	223	248	247
223	224	249	248
224	225	250	249
225	226	251	250
226	227	252	251
227	228	253	252
228	229	254	253
229	230	255	254
230	231	256	255
231	232	257	256
232	233	258	257
233	234	259	258
234	235	260	259
235	236	261	260
212	236	261	237
237	238	263	262
238	239	264	263

239	240	265	264
240	241	266	265
241	242	267	266
242	243	268	267
243	244	269	268
244	245	270	269
245	246	271	270
246	247	272	271
247	248	273	272
248	249	274	273
249	250	275	274
250	251	276	275
251	252	277	276
252	253	278	277
253	254	279	278
254	255	280	279
255	256	281	280
256	257	282	281
257	258	283	282
258	259	284	283
259	260	285	284
260	261	286	285
237	261	286	262
262	263	288	287
263	264	289	288
264	265	290	289
265	266	291	290
266	267	292	291
267	268	293	292
268	269	294	293
269	270	295	294
270	271	296	295
271	272	297	296
272	273	298	297
273	274	299	298
274	275	300	299
275	276	301	300
276	277	302	301
277	278	303	302
278	279	304	303
279	280	305	304
280	281	306	305
281	282	307	306
282	283	308	307
283	284	309	308
284	285	310	309
285	286	311	310
262	286	311	287
287	288	313	312
288	289	314	313
289	290	315	314
290	291	316	315
291	292	317	316
292	293	318	317
293	294	319	318
294	295	320	319
295	296	321	320
296	297	322	321
297	298	323	322
298	299	324	323
299	300	325	324
300	301	326	325
301	302	327	326
302	303	328	327

303	304	329	328
304	305	330	329
305	306	331	330
306	307	332	331
307	308	333	332
308	309	334	333
309	310	335	334
310	311	336	335
287	311	336	312
312	313	338	337
313	314	339	338
314	315	340	339
315	316	341	340
316	317	342	341
317	318	343	342
318	319	344	343
319	320	345	344
320	321	346	345
321	322	347	346
322	323	348	347
323	324	349	348
324	325	350	349
325	326	351	350
326	327	352	351
327	328	353	352
328	329	354	353
329	330	355	354
330	331	356	355
331	332	357	356
332	333	358	357
333	334	359	358
334	335	360	359
335	336	361	360
312	336	361	337

SURFACE 4 NUMBER OF NODES 125 NUMBER OF ELEMENTS 100
CONNECTIVITY MATRIX OF NODE NUMBERS

362	363	388	387
363	364	389	388
364	365	390	389
365	366	391	390
366	367	392	391
367	368	393	392
368	369	394	393
369	370	395	394
370	371	396	395
371	372	397	396
372	373	398	397
373	374	399	398
374	375	400	399
375	376	401	400
376	377	402	401
377	378	403	402
378	379	404	403
379	380	405	404
380	381	406	405
381	382	407	406
382	383	408	407
383	384	409	408
384	385	410	409
385	386	411	410
362	386	411	387
387	388	413	412

388	389	414	413
389	390	415	414
390	391	416	415
391	392	417	416
392	393	418	417
393	394	419	418
394	395	420	419
395	396	421	420
396	397	422	421
397	398	423	422
398	399	424	423
399	400	425	424
400	401	426	425
401	402	427	426
402	403	428	427
403	404	429	428
404	405	430	429
405	406	431	430
406	407	432	431
407	408	433	432
408	409	434	433
409	410	435	434
410	411	436	435
387	411	436	412
412	413	438	437
413	414	439	438
414	415	440	439
415	416	441	440
416	417	442	441
417	418	443	442
418	419	444	443
419	420	445	444
420	421	446	445
421	422	447	446
422	423	448	447
423	424	449	448
424	425	450	449
425	426	451	450
426	427	452	451
427	428	453	452
428	429	454	453
429	430	455	454
430	431	456	455
431	432	457	456
432	433	458	457
433	434	459	458
434	435	460	459
435	436	461	460
412	436	461	437
437	438	463	462
438	439	464	463
439	440	465	464
440	441	466	465
441	442	467	466
442	443	468	467
443	444	469	468
444	445	470	469
445	446	471	470
446	447	472	471
447	448	473	472
448	449	474	473
449	450	475	474
450	451	476	475
451	452	477	476

452	453	478	477
453	454	479	478
454	455	480	479
455	456	481	480
456	457	482	481
457	458	483	482
458	459	484	483
459	460	485	484
460	461	486	485
437	461	486	462

SURFACE 5 NUMBER OF NODES 175 NUMBER OF ELEMENTS 150
CONNECTIVITY MATRIX OF NODE NUMBERS

487	488	513	512
488	489	514	513
489	490	515	514
490	491	516	515
491	492	517	516
492	493	518	517
493	494	519	518
494	495	520	519
495	496	521	520
496	497	522	521
497	498	523	522
498	499	524	523
499	500	525	524
500	501	526	525
501	502	527	526
502	503	528	527
503	504	529	528
504	505	530	529
505	506	531	530
506	507	532	531
507	508	533	532
508	509	534	533
509	510	535	534
510	511	536	535
487	511	536	512
512	513	538	537
513	514	539	538
514	515	540	539
515	516	541	540
516	517	542	541
517	518	543	542
518	519	544	543
519	520	545	544
520	521	546	545
521	522	547	546
522	523	548	547
523	524	549	548
524	525	550	549
525	526	551	550
526	527	552	551
527	528	553	552
528	529	554	553
529	530	555	554
530	531	556	555
531	532	557	556
532	533	558	557
533	534	559	558
534	535	560	559
535	536	561	560
512	536	561	537

537	538	563	562
538	539	564	563
539	540	565	564
540	541	566	565
541	542	567	566
542	543	568	567
543	544	569	568
544	545	570	569
545	546	571	570
546	547	572	571
547	548	573	572
548	549	574	573
549	550	575	574
550	551	576	575
551	552	577	576
552	553	578	577
553	554	579	578
554	555	580	579
555	556	581	580
556	557	582	581
557	558	583	582
558	559	584	583
559	560	585	584
560	561	586	585
537	561	586	562
562	563	588	587
563	564	589	588
564	565	590	589
565	566	591	590
566	567	592	591
567	568	593	592
568	569	594	593
569	570	595	594
570	571	596	595
571	572	597	596
572	573	598	597
573	574	599	598
574	575	600	599
575	576	601	600
576	577	602	601
577	578	603	602
578	579	604	603
579	580	605	604
580	581	606	605
581	582	607	606
582	583	608	607
583	584	609	608
584	585	610	609
585	586	611	610
562	586	611	587
587	588	613	612
588	589	614	613
589	590	615	614
590	591	616	615
591	592	617	616
592	593	618	617
593	594	619	618
594	595	620	619
595	596	621	620
596	597	622	621
597	598	623	622
598	599	624	623
599	600	625	624
600	601	626	625

```
       601        602        627        626
       602        603        628        627
       603        604        629        628
       604        605        630        629
       605        606        631        630
       606        607        632        631
       607        608        633        632
       608        609        634        633
       609        610        635        634
       610        611        636        635
       587        611        636        612
       612        613        638        637
       613        614        639        638
       614        615        640        639
       615        616        641        640
       616        617        642        641
       617        618        643        642
       618        619        644        643
       619        620        645        644
       620        621        646        645
       621        622        647        646
       622        623        648        647
       623        624        649        648
       624        625        650        649
       625        626        651        650
       626        627        652        651
       627        628        653        652
       628        629        654        653
       629        630        655        654
       630        631        656        655
       631        632        657        656
       632        633        658        657
       633        634        659        658
       634        635        660        659
       635        636        661        660
       612        636        661        637
0TOTAL NUMBER OF NODES          661
 TOTAL NUMBER OF ELEMENTS       550

 CPU TIME AT TERMINATION        235.4000 S
```

A.6 3D Plotting File

This is the file generated by TECPLOT and stored as TAPE7. It is generally renamed to another file by the run.shadow command. It is then transferred to a PC under a shorter name.

```
Convex file: microenv/shadow.tp7_sample
Transfered to PC: sh2sam.tec

 TITLE="SHADOWV2 sample file"
  VARIABLES=NODE,PRIM,SPEC,DIFF,RECOMB,REACT,TOTAL,X,Y,Z
 ZONE T="SURF 1",I= 661,J= 550 F=FEPOINT
    1  -14.0248   13.5450   12.1168    9.2745   -3.1877   13.5609   -3.984   -3.984   15.000
    2  -14.0313   13.5499   12.2372    9.2745   -3.1877   13.5705   -3.984   -2.384   15.000
    3  -14.0412   13.5498   12.3668    9.2745   -3.1877   13.5774   -3.984   -0.784   15.000
    4  -14.0411   13.5526   12.3685    9.2745   -3.1877   13.5801   -3.984    0.816   15.000
    5  -14.0310   13.5513   12.2157    9.2745   -3.1877   13.5709   -3.984    2.416   15.000
    6  -14.0248   13.5435   12.0650    9.2745   -3.1877   13.5577   -3.984    3.984   15.000
    7  -14.0313   13.5466   12.1951    9.2745   -3.1877   13.5655   -2.384   -3.984   15.000
    8  -14.0417   13.4795   12.3369    9.2745   -3.1877   13.5097   -2.384   -2.384   15.000
    9  -14.0541   13.3323   12.4816    9.2745   -3.1877   13.3896   -2.384   -0.784   15.000
   10  -14.0539   13.3375   12.4807    9.2745   -3.1877   13.3941   -2.384    0.816   15.000
   11  -14.0412   13.4919   12.3389    9.2745   -3.1877   13.5214   -2.384    2.416   15.000
```

12	-14.0313	13.5580	12.2175	9.2745	-3.1877	13.5774	-2.384	3.984	15.000
13	-14.0424	13.5490	12.3377	9.2745	-3.1877	13.5749	-0.784	-3.984	15.000
14	-14.0586	13.3270	12.4483	9.2745	-3.1877	13.3809	-0.784	-2.384	15.000
15	-14.2114	12.5768	12.5662	9.2745	-3.1877	12.8725	-0.784	-0.784	15.000
16	-14.2027	12.6063	12.5886	9.2745	-3.1877	12.8986	-0.784	0.816	15.000
17	-14.0578	13.3548	12.4585	9.2745	-3.1877	13.4068	-0.784	2.416	15.000
18	-14.0424	13.5557	12.3116	9.2745	-3.1877	13.5798	-0.784	3.984	15.000
19	-14.0422	13.5582	12.3292	9.2745	-3.1877	13.5831	0.816	-3.984	15.000
20	-14.0584	13.3401	12.4490	9.2745	-3.1877	13.3926	0.816	-2.384	15.000
21	-14.2028	12.6023	12.5643	9.2745	-3.1877	12.8848	0.816	-0.784	15.000
22	-14.1947	12.6309	12.5662	9.2745	-3.1877	12.9007	0.816	0.816	15.000
23	-14.0576	13.3492	12.4418	9.2745	-3.1877	13.3999	0.816	2.416	15.000
24	-14.0422	13.5503	12.3350	9.2745	-3.1877	13.5760	0.816	3.984	15.000
25	-14.0310	13.5602	12.1877	9.2745	-3.1877	13.5782	2.416	-3.984	15.000
26	-14.0412	13.4932	12.3264	9.2745	-3.1877	13.5218	2.416	-2.384	15.000
27	-14.0534	13.3495	12.4446	9.2745	-3.1877	13.4005	2.416	-0.784	15.000
28	-14.0532	13.3574	12.4185	9.2745	-3.1877	13.4047	2.416	0.816	15.000
29	-14.0407	13.4957	12.3063	9.2745	-3.1877	13.5229	2.416	2.416	15.000
30	-14.0310	13.5529	12.2396	9.2745	-3.1877	13.5735	2.416	3.984	15.000
31	-14.0248	13.5545	12.1347	9.2745	-3.1877	13.5707	3.984	-3.984	15.000
32	-14.0313	13.5575	12.2173	9.2745	-3.1877	13.5769	3.984	-2.384	15.000
33	-14.0412	13.5506	12.2909	9.2745	-3.1877	13.5739	3.984	-0.784	15.000
34	-14.0411	13.5570	12.3010	9.2745	-3.1877	13.5805	3.984	0.816	15.000
35	-14.0310	13.5588	12.2001	9.2745	-3.1877	13.5774	3.984	2.416	15.000
36	-14.0248	13.5466	12.0725	9.2745	-3.1877	13.5609	3.984	3.984	15.000
37	12.5075	12.5272	12.9704	11.8260	-3.1877	13.2021	3.000	0.008	0.010
38	12.4704	12.5389	12.9660	11.8565	-3.1877	13.1948	2.896	0.784	0.010
39	12.3583	12.5390	12.9155	11.8883	-3.1877	13.1453	2.594	1.507	0.010
40	12.2851	12.4582	12.8911	11.7749	-3.1877	13.0997	2.116	2.127	0.010
41	12.3613	12.4238	12.9256	11.7367	-3.1877	13.1263	1.493	2.602	0.010
42	12.4722	12.4647	12.9801	11.8115	-3.1877	13.1885	0.769	2.900	0.010
43	12.5075	12.4729	13.0615	11.9496	-3.1877	13.2482	-0.008	3.000	0.010
44	12.4704	12.4259	13.0305	11.9950	-3.1877	13.2134	-0.784	2.896	0.010
45	12.3583	12.4314	12.9245	11.8186	-3.1877	13.1267	-1.507	2.594	0.010
46	12.2851	12.4895	12.9099	11.7056	-3.1877	13.1186	-2.127	2.116	0.010
47	12.3613	12.5154	12.9418	11.8700	-3.1877	13.1559	-2.602	1.493	0.010
48	12.4722	12.5274	12.9661	11.9413	-3.1877	13.1927	-2.900	0.769	0.010
49	12.5075	12.4851	13.0090	11.8735	-3.1877	13.2171	-3.000	-0.008	0.010
50	12.4704	12.5077	13.0147	11.9187	-3.1877	13.2179	-2.896	-0.784	0.010
51	12.3583	12.5188	12.9625	11.9017	-3.1877	13.1690	-2.594	-1.507	0.010
52	12.2851	12.4869	12.9447	11.7924	-3.1877	13.1399	-2.116	-2.127	0.010
53	12.3613	12.4963	12.9580	11.7953	-3.1877	13.1617	-1.493	-2.602	0.010
54	12.4722	12.5094	12.9872	11.7771	-3.1877	13.2016	-0.769	-2.900	0.010
55	12.5075	12.5553	12.9975	11.8860	-3.1877	13.2240	0.008	-3.000	0.010
56	12.4704	12.6032	12.9837	11.9626	-3.1877	13.2200	0.784	-2.896	0.010
57	12.3583	12.5213	12.9284	11.9005	-3.1877	13.1487	1.507	-2.594	0.010
58	12.2851	12.4262	12.9005	11.8309	-3.1877	13.0986	2.127	-2.116	0.010
59	12.3613	12.4881	12.9294	11.8800	-3.1877	13.1422	2.602	-1.493	0.010
60	12.4722	12.5284	12.9822	11.9350	-3.1877	13.2025	2.900	-0.769	0.010
61	12.5075	12.5320	13.0071	11.8978	-3.1877	13.2250	3.000	-0.008	0.010
62	12.5075	12.4998	12.8540	11.8774	-3.1877	13.1311	3.000	0.008	1.010
63	12.4700	12.5273	12.8302	11.8561	-3.1877	13.1167	2.896	0.784	1.010
64	12.3403	12.5288	12.7840	11.7225	-3.1877	13.0663	2.594	1.507	1.010
65	12.2489	12.4822	12.7717	11.6395	-3.1877	13.0302	2.116	2.127	1.010
66	12.3442	12.4720	12.7898	11.6612	-3.1877	13.0545	1.493	2.602	1.010
67	12.4719	12.4579	12.8357	11.7574	-3.1877	13.1032	0.769	2.900	1.010
68	12.5075	12.4677	12.9029	11.8593	-3.1877	13.1508	-0.008	3.000	1.010
69	12.4700	12.4874	12.8893	11.8589	-3.1877	13.1390	-0.784	2.896	1.010
70	12.3403	12.4426	12.8047	11.7482	-3.1877	13.0545	-1.507	2.594	1.010
71	12.2489	12.4243	12.7755	11.6013	-3.1877	13.0168	-2.127	2.116	1.010
72	12.3442	12.4824	12.8010	11.6828	-3.1877	13.0633	-2.602	1.493	1.010
73	12.4719	12.5207	12.8196	11.8059	-3.1877	13.1100	-2.900	0.769	1.010
74	12.5075	12.4897	12.8452	11.8310	-3.1877	13.1241	-3.000	-0.008	1.010
75	12.4700	12.5032	12.8528	11.8388	-3.1877	13.1226	-2.896	-0.784	1.010

76	12.3403	12.5087	12.8231	11.7517	-3.1877	13.0817	-2.594	-1.507	1.010
77	12.2489	12.4924	12.8022	11.6747	-3.1877	13.0501	-2.116	-2.127	1.010
78	12.3442	12.5163	12.8163	11.7485	-3.1877	13.0807	-1.493	-2.602	1.010
79	12.4719	12.5173	12.8486	11.7856	-3.1877	13.1242	-0.769	-2.900	1.010
80	12.5075	12.5324	12.8451	11.8064	-3.1877	13.1344	0.008	-3.000	1.010
81	12.4700	12.5485	12.8292	11.7756	-3.1877	13.1217	0.784	-2.896	1.010
82	12.3403	12.5009	12.7923	11.7458	-3.1877	13.0628	1.507	-2.594	1.010
83	12.2489	12.4755	12.7758	11.7455	-3.1877	13.0306	2.127	-2.116	1.010
84	12.3442	12.5203	12.8105	11.7372	-3.1877	13.0787	2.602	-1.493	1.010
85	12.4719	12.5228	12.8587	11.7614	-3.1877	13.1309	2.900	-0.769	1.010
86	12.5075	12.5018	12.8783	11.8060	-3.1877	13.1446	3.000	-0.008	1.010
87	12.4681	12.5042	12.5463	11.7772	-3.1877	12.9845	3.000	0.008	2.010
88	12.4476	12.5083	12.5322	11.7615	-3.1877	12.9746	2.896	0.784	2.010
89	12.3103	12.4976	12.5218	11.5181	-3.1877	12.9301	2.594	1.507	2.010
90	12.1787	12.5057	12.5194	11.3632	-3.1877	12.9042	2.116	2.127	2.010
91	12.3166	12.4996	12.4687	11.4827	-3.1877	12.9125	1.493	2.602	2.010
92	12.4488	12.4452	12.4776	11.6457	-3.1877	12.9346	0.769	2.900	2.010
93	12.4681	12.4784	12.5187	11.7235	-3.1877	12.9660	-0.008	3.000	2.010
94	12.4476	12.5614	12.5215	11.6997	-3.1877	12.9898	-0.784	2.896	2.010
95	12.3103	12.5018	12.4786	11.6659	-3.1877	12.9154	-1.507	2.594	2.010
96	12.1787	12.4305	12.4203	11.4835	-3.1877	12.8348	-2.127	2.116	2.010
97	12.3166	12.4865	12.4675	11.5052	-3.1877	12.9070	-2.602	1.493	2.010
98	12.4488	12.4977	12.5076	11.7112	-3.1877	12.9626	-2.900	0.769	2.010
99	12.4681	12.4678	12.4928	11.7340	-3.1877	12.9535	-3.000	-0.008	2.010
100	12.4476	12.4745	12.4690	11.6641	-3.1877	12.9410	-2.896	-0.784	2.010
101	12.3103	12.4800	12.4666	11.5685	-3.1877	12.9026	-2.594	-1.507	2.010
102	12.1787	12.4845	12.4400	11.5582	-3.1877	12.8642	-2.116	-2.127	2.010
103	12.3166	12.5028	12.4771	11.6670	-3.1877	12.9167	-1.493	-2.602	2.010
104	12.4488	12.5124	12.5551	11.6779	-3.1877	12.9847	-0.769	-2.900	2.010
105	12.4681	12.5186	12.5281	11.6767	-3.1877	12.9828	0.008	-3.000	2.010
106	12.4476	12.4908	12.5035	11.5573	-3.1877	12.9584	0.784	-2.896	2.010
107	12.3103	12.4769	12.4844	11.5231	-3.1877	12.9081	1.507	-2.594	2.010
108	12.1787	12.5095	12.4891	11.5842	-3.1877	12.8935	2.127	-2.116	2.010
109	12.3166	12.5220	12.5637	11.5789	-3.1877	12.9572	2.602	-1.493	2.010
110	12.4488	12.5106	12.5821	11.5799	-3.1877	12.9944	2.900	-0.769	2.010
111	12.4681	12.5037	12.5501	11.6403	-3.1877	12.9857	3.000	-0.008	2.010
112	12.3322	12.5252	12.1970	11.4334	-3.1877	12.8497	3.000	0.008	3.010
113	12.3321	12.5275	12.2151	11.4628	-3.1877	12.8548	2.896	0.784	3.010
114	12.2382	12.4944	12.2479	11.4818	-3.1877	12.8210	2.594	1.507	3.010
115	12.1224	12.4891	12.2561	11.4469	-3.1877	12.7933	2.116	2.127	3.010
116	12.2443	12.4819	12.1880	11.4921	-3.1877	12.8014	1.493	2.602	3.010
117	12.3321	12.4640	12.1601	11.5685	-3.1877	12.8132	0.769	2.900	3.010
118	12.3322	12.5073	12.1651	11.5773	-3.1877	12.8343	-0.008	3.000	3.010
119	12.3321	12.5659	12.2002	11.5805	-3.1877	12.8701	-0.784	2.896	3.010
120	12.2382	12.5362	12.2325	11.5366	-3.1877	12.8373	-1.507	2.594	3.010
121	12.1224	12.4920	12.1793	11.4753	-3.1877	12.7739	-2.127	2.116	3.010
122	12.2443	12.5031	12.1869	11.5577	-3.1877	12.8114	-2.602	1.493	3.010
123	12.3321	12.5189	12.2355	11.7004	-3.1877	12.8556	-2.900	0.769	3.010
124	12.3322	12.5024	12.1825	11.6002	-3.1877	12.8357	-3.000	-0.008	3.010
125	12.3321	12.4845	12.1075	11.5950	-3.1877	12.8116	-2.896	-0.784	3.010
126	12.2382	12.4576	12.1944	11.6196	-3.1877	12.7898	-2.594	-1.507	3.010
127	12.1224	12.4575	12.1975	11.5133	-3.1877	12.7611	-2.116	-2.127	3.010
128	12.2443	12.4913	12.1939	11.5200	-3.1877	12.8073	-1.493	-2.602	3.010
129	12.3321	12.5017	12.2548	11.4639	-3.1877	12.8525	-0.769	-2.900	3.010
130	12.3322	12.5101	12.2215	11.5305	-3.1877	12.8482	0.008	-3.000	3.010
131	12.3321	12.5221	12.2111	11.5567	-3.1877	12.8514	0.784	-2.896	3.010
132	12.2382	12.5356	12.2101	11.5198	-3.1877	12.8315	1.507	-2.594	3.010
133	12.1224	12.5155	12.2027	11.5357	-3.1877	12.7922	2.127	-2.116	3.010
134	12.2443	12.4721	12.2696	11.5609	-3.1877	12.8183	2.602	-1.493	3.010
135	12.3321	12.4708	12.2616	11.5252	-3.1877	12.8408	2.900	-0.769	3.010
136	12.3322	12.4965	12.1927	11.4772	-3.1877	12.8353	3.000	-0.008	3.010
137	12.2357	12.5583	11.8561	11.5450	-3.1877	12.7821	3.000	0.008	4.010
138	12.2053	12.5675	11.8046	11.3594	-3.1877	12.7735	2.896	0.784	4.010
139	12.1363	12.5210	11.7610	11.3241	-3.1877	12.7214	2.594	1.507	4.010

140	12.1011	12.5088	11.8611	11.4596	-3.1877	12.7173	2.116	2.127	4.010
141	12.1385	12.5284	11.9056	11.4997	-3.1877	12.7448	1.493	2.602	4.010
142	12.2069	12.5364	11.8535	11.5560	-3.1877	12.7606	0.769	2.900	4.010
143	12.2364	12.5217	11.8371	11.4562	-3.1877	12.7585	-0.008	3.000	4.010
144	12.2053	12.5173	11.9397	11.3942	-3.1877	12.7608	-0.784	2.896	4.010
145	12.1363	12.4847	12.0197	11.3746	-3.1877	12.7378	-1.507	2.594	4.010
146	12.1011	12.4414	11.9655	11.3894	-3.1877	12.6945	-2.127	2.116	4.010
147	12.1385	12.4948	11.8815	11.5077	-3.1877	12.7211	-2.602	1.493	4.010
148	12.2069	12.5358	11.8427	11.5447	-3.1877	12.7589	-2.900	0.769	4.010
149	12.2364	12.5308	11.7221	11.4309	-3.1877	12.7517	-3.000	-0.008	4.010
150	12.2053	12.5279	11.7305	11.5016	-3.1877	12.7415	-2.896	-0.784	4.010
151	12.1363	12.4903	11.9060	11.5306	-3.1877	12.7216	-2.594	-1.507	4.010
152	12.1011	12.4574	11.9278	11.4052	-3.1877	12.6968	-2.116	-2.127	4.010
153	12.1385	12.5063	11.8440	11.3923	-3.1877	12.7229	-1.493	-2.602	4.010
154	12.2069	12.5292	11.7783	11.4271	-3.1877	12.7476	-0.769	-2.900	4.010
155	12.2364	12.5287	11.6968	11.4829	-3.1877	12.7481	0.008	-3.000	4.010
156	12.2053	12.5590	11.7719	11.4994	-3.1877	12.7648	0.784	-2.896	4.010
157	12.1363	12.5335	11.8711	11.4525	-3.1877	12.7426	1.507	-2.594	4.010
158	12.1011	12.4948	11.7899	11.5129	-3.1877	12.6993	2.127	-2.116	4.010
159	12.1385	12.4664	11.7383	11.4694	-3.1877	12.6858	2.602	-1.493	4.010
160	12.2069	12.4725	11.7205	11.4551	-3.1877	12.7079	2.900	-0.769	4.010
161	12.2357	12.5290	11.7223	11.5541	-3.1877	12.7504	3.000	-0.008	4.010
162	12.2356	12.5929	11.7435	11.6844	-3.1877	12.7917	3.000	0.008	4.990
163	12.1873	12.5850	11.7296	11.4846	-3.1877	12.7724	2.896	0.784	4.990
164	12.1150	12.5323	11.5959	11.2745	-3.1877	12.7079	2.594	1.507	4.990
165	12.1011	12.5370	11.7058	11.3677	-3.1877	12.7171	2.116	2.127	4.990
166	12.1158	12.5667	11.8097	11.4308	-3.1877	12.7511	1.493	2.602	4.990
167	12.1900	12.5733	11.7488	11.5613	-3.1877	12.7674	0.769	2.900	4.990
168	12.2366	12.5222	11.7806	11.4820	-3.1877	12.7525	-0.008	3.000	4.990
169	12.1873	12.4826	11.8486	11.4045	-3.1877	12.7229	-0.784	2.896	4.990
170	12.1150	12.4397	11.8315	11.3784	-3.1877	12.6752	-1.507	2.594	4.990
171	12.1011	12.3973	11.7848	11.3306	-3.1877	12.6403	-2.127	2.116	4.990
172	12.1158	12.5019	11.7522	11.5058	-3.1877	12.7030	-2.602	1.493	4.990
173	12.1900	12.5227	11.6868	11.5049	-3.1877	12.7297	-2.900	0.769	4.990
174	12.2366	12.5091	11.6127	11.3703	-3.1877	12.7294	-3.000	-0.008	4.990
175	12.1873	12.5377	11.6736	11.3957	-3.1877	12.7372	-2.896	-0.784	4.990
176	12.1150	12.5184	11.6958	11.4007	-3.1877	12.7075	-2.594	-1.507	4.990
177	12.1011	12.4701	11.6713	11.3956	-3.1877	12.6705	-2.116	-2.127	4.990
178	12.1158	12.5032	11.6354	11.4086	-3.1877	12.6922	-1.493	-2.602	4.990
179	12.1900	12.5474	11.6292	11.4284	-3.1877	12.7405	-0.769	-2.900	4.990
180	12.2366	12.5593	11.5509	11.5505	-3.1877	12.7562	0.008	-3.000	4.990
181	12.1873	12.5692	11.6513	11.5191	-3.1877	12.7555	0.784	-2.896	4.990
182	12.1150	12.4825	11.7291	11.3945	-3.1877	12.6881	1.507	-2.594	4.990
183	12.1011	12.4613	11.5565	11.4983	-3.1877	12.6546	2.127	-2.116	4.990
184	12.1158	12.4764	11.5513	11.4499	-3.1877	12.6681	2.602	-1.493	4.990
185	12.1900	12.5038	11.4698	11.5275	-3.1877	12.7019	2.900	-0.769	4.990
186	12.2356	12.5854	11.4687	11.6850	-3.1877	12.7682	3.000	-0.008	4.990
187	12.8520	12.8703	11.2430	9.2745	12.1326	13.1675	2.995	0.008	5.008
188	12.7846	12.8592	11.2161	9.2745	12.1175	13.1299	2.891	0.783	5.008
189	12.5526	12.8785	11.3954	9.2745	12.0628	13.0561	2.590	1.504	5.008
190	12.3536	12.9231	11.4843	9.2745	12.1052	13.0390	2.113	2.124	5.008
191	12.5597	12.8757	11.4140	9.2745	12.1751	13.0569	1.491	2.598	5.008
192	12.7879	12.8503	11.2918	9.2745	12.2357	13.1276	0.768	2.895	5.008
193	12.8520	12.8548	11.0763	9.2745	12.2234	13.1580	-0.008	2.995	5.008
194	12.7846	12.8366	11.3260	9.2745	12.0897	13.1194	-0.783	2.891	5.008
195	12.5526	12.9129	11.5481	9.2745	12.0647	13.0830	-1.504	2.590	5.008
196	12.3536	12.9463	11.5247	9.2745	11.9700	13.0580	-2.124	2.113	5.008
197	12.5597	12.8918	11.4477	9.2745	11.9875	13.0683	-2.598	1.491	5.008
198	12.7879	12.8091	11.5111	9.2745	12.0977	13.1107	-2.895	0.768	5.008
199	12.8520	12.8838	11.5322	9.2745	12.1708	13.1791	-2.995	-0.008	5.008
200	12.7846	12.9195	11.2702	9.2745	12.1152	13.1638	-2.891	-0.783	5.008
201	12.5526	12.8626	11.2519	9.2745	11.9900	13.0428	-2.590	-1.504	5.008
202	12.3536	12.8792	11.2938	9.2745	12.0130	13.0011	-2.113	-2.124	5.008
203	12.5597	12.8527	11.1507	9.2745	11.9316	13.0372	-1.491	-2.598	5.008

204	12.7879	12.8192	11.3413	9.2745	12.0348	13.1123	-0.768	-2.895	5.008
205	12.8520	12.8033	11.3718	9.2745	12.1506	13.1369	0.008	-2.995	5.008
206	12.7846	12.8180	11.4100	9.2745	12.1166	13.1113	0.783	-2.891	5.008
207	12.5526	12.8419	11.4545	9.2745	11.9819	13.0336	1.504	-2.590	5.008
208	12.3536	12.8671	11.2023	9.2745	11.9637	12.9904	2.124	-2.113	5.008
209	12.5597	12.8138	11.1446	9.2745	12.0133	13.0121	2.598	-1.491	5.008
210	12.7879	12.7945	11.2544	9.2745	12.0699	13.0985	2.895	-0.768	5.008
211	12.8520	12.8664	11.2197	9.2745	12.1329	13.1652	2.995	-0.008	5.008
212	12.5985	12.8114	11.5644	9.2745	11.9752	13.0339	2.495	0.007	5.841
213	12.5338	12.8142	11.5203	9.2745	11.9342	13.0115	2.409	0.652	5.841
214	12.3191	12.8511	11.4038	9.2745	11.9292	12.9748	2.158	1.253	5.841
215	12.1407	12.8985	11.3706	9.2745	12.0029	12.9793	1.760	1.769	5.841
216	12.3254	12.8688	11.3665	9.2745	12.0440	12.9886	1.242	2.164	5.841
217	12.5369	12.8333	11.3511	9.2745	12.0731	13.0203	0.640	2.412	5.841
218	12.5997	12.8307	11.1817	9.2745	12.0734	13.0375	-0.007	2.495	5.841
219	12.5338	12.8222	11.4466	9.2745	12.0510	13.0145	-0.652	2.409	5.841
220	12.3191	12.8700	11.5486	9.2745	12.0227	12.9935	-1.253	2.158	5.841
221	12.1407	12.8838	11.4604	9.2745	11.9100	12.9696	-1.769	1.760	5.841
222	12.3254	12.8086	11.5123	9.2745	11.8905	12.9483	-2.164	1.242	5.841
223	12.5369	12.7761	11.5342	9.2745	11.9540	12.9893	-2.412	0.640	5.841
224	12.5997	12.8450	11.5045	9.2745	11.9959	13.0529	-2.495	-0.007	5.841
225	12.5338	12.8545	11.3665	9.2745	11.9427	13.0336	-2.409	-0.652	5.841
226	12.3191	12.8235	11.2995	9.2745	11.9373	12.9516	-2.158	-1.253	5.841
227	12.1407	12.8571	11.2957	9.2745	11.9887	12.9433	-1.760	-1.769	5.841
228	12.3254	12.8300	11.4198	9.2745	11.9404	12.9609	-1.242	-2.164	5.841
229	12.5369	12.8034	11.4272	9.2745	12.0300	13.0030	-0.640	-2.412	5.841
230	12.5997	12.8099	11.2703	9.2745	12.1157	13.0261	0.007	-2.495	5.841
231	12.5338	12.8221	11.4132	9.2745	12.0555	13.0135	0.652	-2.409	5.841
232	12.3191	12.8338	11.5187	9.2745	11.9518	12.9654	1.253	-2.158	5.841
233	12.1407	12.8446	11.4285	9.2745	11.9229	12.9366	1.769	-1.760	5.841
234	12.3254	12.8029	11.2954	9.2745	11.9112	12.9378	2.164	-1.242	5.841
235	12.5369	12.7803	11.2862	9.2745	12.0057	12.9852	2.412	-0.640	5.841
236	12.5997	12.8194	11.4309	9.2745	12.0453	13.0352	2.495	-0.007	5.841
237	11.6834	12.4994	11.6470	9.2745	11.4790	12.6111	1.996	0.005	6.674
238	11.6311	12.5228	11.6043	9.2745	11.3927	12.6194	1.926	0.522	6.674
239	11.4721	12.5905	11.4838	9.2745	11.5224	12.6529	1.726	1.002	6.674
240	11.3428	12.6189	11.4322	9.2745	11.6438	12.6674	1.407	1.415	6.674
241	11.4764	12.6085	11.5422	9.2745	11.5598	12.6728	0.993	1.731	6.674
242	11.6335	12.5625	11.5833	9.2745	11.5304	12.6498	0.511	1.929	6.674
243	11.6929	12.5525	11.5248	9.2745	11.6083	12.6431	-0.005	1.996	6.674
244	11.6311	12.5841	11.5561	9.2745	11.7579	12.6652	-0.522	1.926	6.674
245	11.4721	12.5855	11.5540	9.2745	11.7792	12.6537	-1.002	1.726	6.674
246	11.3428	12.5717	11.5230	9.2745	11.6431	12.6318	-1.415	1.407	6.674
247	11.4764	12.4998	11.5306	9.2745	11.5526	12.5797	-1.731	0.993	6.674
248	11.6335	12.5123	11.4627	9.2745	11.5077	12.5991	-1.929	0.511	6.674
249	11.6929	12.5538	11.4867	9.2745	11.4614	12.6414	-1.996	-0.005	6.674
250	11.6311	12.5301	11.5560	9.2745	11.4353	12.6208	-1.926	-0.522	6.674
251	11.4721	12.5382	11.4681	9.2745	11.6621	12.6068	-1.726	-1.002	6.674
252	11.3428	12.5907	11.4813	9.2745	11.7315	12.6454	-1.407	-1.415	6.674
253	11.4764	12.5838	11.6426	9.2745	11.7044	12.6603	-0.993	-1.731	6.674
254	11.6335	12.5502	11.5369	9.2745	11.7738	12.6359	-0.511	-1.929	6.674
255	11.6929	12.5735	11.3347	9.2745	11.8151	12.6488	0.005	-1.996	6.674
256	11.6311	12.5924	11.5345	9.2745	11.7300	12.6705	0.522	-1.926	6.674
257	11.4721	12.5913	11.6001	9.2745	11.7070	12.6625	1.002	-1.726	6.674
258	11.3428	12.5971	11.5140	9.2745	11.7242	12.6534	1.415	-1.407	6.674
259	11.4764	12.5566	11.2760	9.2745	11.5927	12.6118	1.731	-0.993	6.674
260	11.6335	12.5111	11.3432	9.2745	11.5884	12.5905	1.929	-0.511	6.674
261	11.6929	12.5082	11.5796	9.2745	11.6285	12.6123	1.996	-0.005	6.674
262	10.6377	11.6550	11.5272	9.2745	11.1082	11.9201	1.496	0.004	7.507
263	10.5942	11.6834	11.4394	9.2745	10.9300	11.9013	1.444	0.391	7.507
264	10.3614	11.7659	11.4969	9.2745	10.7833	11.9639	1.293	0.751	7.507
265	10.0724	11.6789	11.6009	9.2745	10.9870	11.9485	1.055	1.060	7.507
266	10.3697	11.6297	11.6542	9.2745	10.6626	11.9546	0.745	1.297	7.507
267	10.5966	11.6075	11.5636	9.2745	10.5946	11.9088	0.383	1.446	7.507

268	10.6509	11.6158	11.5512	9.2745	10.9639	11.9103	−0.004	1.496	7.507
269	10.5942	11.7704	11.4199	9.2745	10.9376	11.9502	−0.391	1.444	7.507
270	10.3614	11.7629	11.4892	9.2745	11.2334	11.9594	−0.751	1.293	7.507
271	10.0724	11.7508	11.6384	9.2745	11.2679	12.0044	−1.060	1.055	7.507
272	10.3697	11.7541	11.5484	9.2745	10.9586	11.9752	−1.297	0.745	7.507
273	10.5966	11.7106	11.3318	9.2745	10.7017	11.8852	−1.446	0.383	7.507
274	10.6509	11.6715	11.4527	9.2745	10.6333	11.9019	−1.496	−0.004	7.507
275	10.5942	11.6698	11.6693	9.2745	10.9968	11.9885	−1.444	−0.391	7.507
276	10.3614	11.6848	11.6156	9.2745	11.1015	11.9636	−1.293	−0.751	7.507
277	10.0724	11.7020	11.5274	9.2745	10.9007	11.9305	−1.055	−1.060	7.507
278	10.3697	11.7884	11.5404	9.2745	10.6932	11.9934	−0.745	−1.297	7.507
279	10.5966	11.6787	11.5812	9.2745	10.9226	11.9533	−0.383	−1.446	7.507
280	10.6509	11.6184	11.5795	9.2745	10.9715	11.9242	0.004	−1.496	7.507
281	10.5942	11.6871	11.6376	9.2745	10.9447	11.9822	0.391	−1.444	7.507
282	10.3614	11.7176	11.4773	9.2745	11.0391	11.9269	0.751	−1.293	7.507
283	10.0724	11.7959	11.3663	9.2745	11.2484	11.9392	1.060	−1.055	7.507
284	10.3697	11.6832	11.3789	9.2745	10.9503	11.8721	1.297	−0.745	7.507
285	10.5966	11.5384	11.5542	9.2745	10.5727	11.8711	1.446	−0.383	7.507
286	10.6509	11.5885	11.6683	9.2745	10.9698	11.9535	1.496	−0.004	7.507
287	9.0084	−13.7830	11.4557	9.2745	10.7722	11.4572	0.996	0.003	8.340
288	8.9395	−20.1670	11.3807	9.2745	10.3491	11.3823	0.962	0.260	8.340
289	8.7809	−20.1670	11.4914	9.2745	−1.1877	11.4923	0.861	0.500	8.340
290	8.6880	6.7263	11.5932	9.2745	10.3278	11.5937	0.703	0.706	8.340
291	8.7842	6.7032	11.5616	9.2745	10.4124	11.5623	0.496	0.864	8.340
292	8.9426	−20.1670	11.4037	9.2745	10.0215	11.4052	0.255	0.963	8.340
293	9.0237	1.2739	11.4924	9.2745	10.3779	11.4939	−0.003	0.996	8.340
294	8.9395	1.2513	11.5689	9.2745	10.7918	11.5699	−0.260	0.962	8.340
295	8.7809	−20.1670	11.5853	9.2745	10.9294	11.5860	−0.500	0.861	8.340
296	8.6880	−20.1670	11.4935	9.2745	10.8330	11.4942	−0.706	0.703	8.340
297	8.7842	−5.0527	11.5118	9.2745	10.2482	11.5126	−0.864	0.496	8.340
298	8.9426	−20.1670	11.5438	9.2745	9.5993	11.5449	−0.963	0.255	8.340
299	9.0237	−15.2404	11.3923	9.2745	10.3844	11.3942	−0.996	−0.003	8.340
300	8.9395	−16.6409	11.4578	9.2745	10.9429	11.4591	−0.962	−0.260	8.340
301	8.7809	−20.1670	11.6518	9.2745	10.9201	11.6524	−0.861	−0.500	8.340
302	8.6880	−5.7755	11.6597	9.2745	7.6115	11.6602	−0.703	−0.706	8.340
303	8.7842	7.2748	11.5524	9.2745	10.1967	11.5532	−0.496	−0.864	8.340
304	8.9426	7.2502	11.4578	9.2745	10.6193	11.4592	−0.255	−0.963	8.340
305	9.0237	7.2762	11.4896	9.2745	10.3721	11.4911	0.003	−0.996	8.340
306	8.9395	7.2517	11.4529	9.2745	9.9463	11.4542	0.260	−0.962	8.340
307	8.7809	−20.1670	11.0667	9.2745	9.9010	11.0690	0.500	−0.861	8.340
308	8.6880	−20.1670	11.4018	9.2745	9.9892	11.4026	0.706	−0.703	8.340
309	8.7842	0.8410	11.4933	9.2745	9.9893	11.4941	0.864	−0.496	8.340
310	8.9426	0.8179	11.5729	9.2745	10.5030	11.5739	0.963	−0.255	8.340
311	9.0237	−14.1013	11.6828	9.2745	10.7882	11.6837	0.996	−0.003	8.340
312	6.9347	−13.8117	11.6468	9.2745	6.5674	11.6468	0.497	0.001	9.171
313	6.8265	−7.0416	11.5155	9.2745	6.4019	11.5155	0.480	0.130	9.171
314	6.5066	−7.0687	11.2073	9.2745	7.7508	11.2073	0.430	0.250	9.171
315	6.1770	−0.1825	11.3958	9.2745	7.7271	11.3958	0.351	0.353	9.171
316	6.5152	−0.2056	11.3475	9.2745	5.4205	11.3475	0.248	0.431	9.171
317	6.8316	0.4616	11.0952	9.2745	9.8664	11.0953	0.128	0.481	9.171
318	6.9575	1.3086	11.2420	9.2745	9.7416	11.2421	−0.001	0.497	9.171
319	6.8265	1.2225	11.4655	9.2745	10.6576	11.4655	−0.130	0.480	9.171
320	6.5066	−2.5559	11.4259	9.2745	10.6324	11.4259	−0.250	0.430	9.171
321	6.1770	−2.5791	10.9449	9.2745	5.0569	10.9449	−0.353	0.351	9.171
322	6.5152	−5.9607	11.5256	9.2745	11.3183	11.5256	−0.431	0.248	9.171
323	6.8316	−5.9911	11.6271	9.2745	11.3419	11.6271	−0.481	0.128	9.171
324	6.9575	−15.2721	11.0639	9.2745	10.3558	11.0639	−0.497	−0.001	9.171
325	6.8265	−16.7632	10.5778	9.2745	10.6582	10.5779	−0.480	−0.130	9.171
326	6.5066	−12.5934	11.3029	9.2745	10.6372	11.3029	−0.430	−0.250	9.171
327	6.1770	−12.6141	11.4824	9.2745	−1.1165	11.4824	−0.351	−0.353	9.171
328	6.5152	7.2463	11.3676	9.2745	10.1673	11.3677	−0.248	−0.431	9.171
329	6.8316	7.2216	11.3799	9.2745	10.3293	11.3799	−0.128	−0.481	9.171
330	6.9575	7.2476	11.3347	9.2745	9.7607	11.3348	0.001	−0.497	9.171
331	6.8265	7.2231	11.4448	9.2745	5.8122	11.4448	0.130	−0.480	9.171

332	6.5066	-7.0051	11.3513	9.2745	5.5043	11.3513	0.250	-0.430	9.171
333	6.1770	-7.0283	11.1890	9.2745	5.1775	11.1890	0.353	-0.351	9.171
334	6.5152	-17.3048	11.1129	9.2745	5.5133	11.1129	0.431	-0.248	9.171
335	6.8316	-18.1670	11.1148	9.2745	5.8283	11.1149	0.481	-0.128	9.171
336	6.9575	-14.1299	11.4762	9.2745	6.3638	11.4762	0.497	-0.001	9.171
337	-0.1877	-20.1670	11.7995	9.2745	6.5903	11.7995	0.050	0.000	9.917
338	-0.1877	-6.7513	11.6046	9.2745	6.3910	11.6046	0.048	0.013	9.917
339	-0.1877	-6.7784	-11.4877	9.2745	8.0362	-0.1877	0.043	0.025	9.917
340	-0.1877	-6.0071	11.1713	9.2745	8.0130	11.1713	0.035	0.035	9.917
341	-0.1877	-6.0366	11.1450	9.2745	-1.1877	11.1450	0.025	0.043	9.917
342	-0.1877	0.7519	-11.4877	9.2745	-1.1877	0.7991	0.013	0.048	9.917
343	-0.1877	0.7287	7.7371	9.2745	-1.1877	7.7371	-0.000	0.050	9.917
344	-0.1877	-20.1670	10.6579	9.2745	-1.1877	10.6579	-0.013	0.048	9.917
345	-0.1877	-2.2656	10.6315	9.2745	-1.1877	10.6315	-0.025	0.043	9.917
346	-0.1877	-2.2888	-11.4877	9.2745	-1.1877	-0.1842	-0.035	0.035	9.917
347	-0.1877	-5.6722	11.6075	9.2745	11.6073	11.6075	-0.043	0.025	9.917
348	-0.1877	-5.7008	11.5816	9.2745	11.5814	11.5816	-0.048	0.013	9.917
349	-0.1877	-20.1670	-11.4877	9.2745	7.7207	-0.1877	-0.050	-0.000	9.917
350	-0.1877	-20.1670	9.5172	9.2745	-1.1877	9.5172	-0.048	-0.013	9.917
351	-0.1877	-12.3031	9.4972	9.2745	-1.1877	9.4972	-0.043	-0.025	9.917
352	-0.1877	-12.3258	-11.4877	9.2745	-1.0587	-0.1877	-0.035	-0.035	9.917
353	-0.1877	-15.6926	9.3681	9.2745	-1.0645	9.3681	-0.025	-0.043	9.917
354	-0.1877	-17.6047	11.4517	9.2745	-1.1877	11.4517	-0.013	-0.048	9.917
355	-0.1877	-17.6337	11.4221	9.2745	-1.1877	11.4221	0.000	-0.050	9.917
356	-0.1877	-20.1670	11.6078	9.2745	-1.1877	11.6078	0.013	-0.048	9.917
357	-0.1877	-6.7148	11.5813	9.2745	-1.1877	11.5813	0.025	-0.043	9.917
358	-0.1877	-6.7380	9.5021	9.2745	-1.1877	9.5021	0.035	-0.035	9.917
359	-0.1877	-17.1814	9.9512	9.2745	-1.1877	9.9512	0.043	-0.025	9.917
360	-0.1877	-20.1670	9.7238	9.2745	-1.1877	9.7238	0.048	-0.013	9.917
361	-0.1877	-20.1670	11.2940	9.2745	6.2719	11.2940	0.050	-0.000	9.917
362	14.0123	12.2843	12.2192	12.7193	-3.1877	14.0271	5.993	-0.016	0.000
363	14.0118	12.3132	12.1600	12.7193	-3.1877	14.0264	5.785	-1.566	0.000
364	13.9702	12.4033	12.0358	12.6762	-3.1877	13.9867	5.182	-3.010	0.000
365	13.9274	12.4035	12.1122	12.6398	-3.1877	13.9466	4.227	-4.249	0.000
366	13.9726	12.3427	12.0960	12.6881	-3.1877	13.9883	2.983	-5.198	0.000
367	14.0118	12.3416	12.0782	12.7302	-3.1877	14.0259	1.536	-5.793	0.000
368	14.0123	12.2612	12.0643	12.7298	-3.1877	14.0247	-0.016	-5.993	0.000
369	14.0118	12.3193	12.0143	12.7227	-3.1877	14.0248	-1.566	-5.785	0.000
370	13.9702	12.3475	11.9700	12.6787	-3.1877	13.9847	-3.010	-5.182	0.000
371	13.9274	12.3684	11.9646	12.6413	-3.1877	13.9438	-4.249	-4.227	0.000
372	13.9726	12.3689	11.9983	12.6881	-3.1877	13.9878	-5.198	-2.983	0.000
373	14.0118	12.2937	12.0159	12.7245	-3.1877	14.0244	-5.793	-1.536	0.000
374	14.0123	12.2768	12.0352	12.7178	-3.1877	14.0247	-5.993	0.016	0.000
375	14.0118	12.3146	11.9487	12.7151	-3.1877	14.0241	-5.785	1.566	0.000
376	13.9702	12.3049	12.0791	12.6794	-3.1877	13.9849	-5.182	3.010	0.000
377	13.9274	12.2559	12.1907	12.6421	-3.1877	13.9443	-4.227	4.249	0.000
378	13.9726	12.3247	12.1678	12.7048	-3.1877	13.9889	-2.983	5.198	0.000
379	14.0118	12.3301	12.1368	12.7349	-3.1877	14.0264	-1.536	5.793	0.000
380	14.0123	12.3365	12.0488	12.7195	-3.1877	14.0259	0.016	5.993	0.000
381	14.0118	12.3533	12.0078	12.7248	-3.1877	14.0254	1.566	5.785	0.000
382	13.9702	12.3336	12.0981	12.6841	-3.1877	13.9858	3.010	5.182	0.000
383	13.9274	12.3176	12.0840	12.6360	-3.1877	13.9439	4.249	4.227	0.000
384	13.9726	12.3128	12.0400	12.6761	-3.1877	13.9870	5.198	2.983	0.000
385	14.0118	12.2702	12.0101	12.7135	-3.1877	14.0239	5.793	1.536	0.000
386	14.0123	12.2419	12.0437	12.7170	-3.1877	14.0241	5.993	0.016	0.000
387	13.9620	12.4026	12.1223	12.6759	-3.1877	13.9799	5.243	-0.014	0.000
388	13.9515	12.4530	12.1068	12.6667	-3.1877	13.9711	5.061	-1.370	0.000
389	13.9121	12.5390	12.1235	12.6330	-3.1877	13.9368	4.534	-2.633	0.000
390	13.8894	12.5279	12.2014	12.6208	-3.1877	13.9164	3.698	-3.717	0.000
391	13.9137	12.5027	12.1542	12.6418	-3.1877	13.9374	2.610	-4.547	0.000
392	13.9521	12.4436	12.1123	12.6738	-3.1877	13.9714	1.344	-5.068	0.000
393	13.9626	12.3784	12.1023	12.6874	-3.1877	13.9796	-0.014	-5.243	0.000
394	13.9515	12.4702	12.0798	12.6682	-3.1877	13.9713	-1.370	-5.061	0.000
395	13.9121	12.5079	12.0223	12.6248	-3.1877	13.9342	-2.633	-4.534	0.000

396	13.8894	12.5434	12.0338	12.6018	-3.1877	13.9143	-3.717	-3.698	0.000
397	13.9137	12.5778	12.0717	12.6344	-3.1877	13.9392	-4.547	-2.610	0.000
398	13.9521	12.4732	12.0843	12.6693	-3.1877	13.9719	-5.068	-1.344	0.000
399	13.9626	12.3971	12.1778	12.6807	-3.1877	13.9811	-5.243	0.014	0.000
400	13.9515	12.4422	12.1275	12.6729	-3.1877	13.9710	-5.061	1.370	0.000
401	13.9121	12.4866	12.1348	12.6361	-3.1877	13.9350	-4.534	2.633	0.000
402	13.8894	12.5384	12.2422	12.6133	-3.1877	13.9176	-3.698	3.717	0.000
403	13.9137	12.5385	12.2177	12.6443	-3.1877	13.9399	-2.610	4.547	0.000
404	13.9521	12.4862	12.1175	12.6745	-3.1877	13.9728	-1.344	5.068	0.000
405	13.9626	12.4440	12.0876	12.6808	-3.1877	13.9811	0.014	5.243	0.000
406	13.9515	12.4794	12.1263	12.6689	-3.1877	13.9722	1.370	5.061	0.000
407	13.9121	12.5250	12.0880	12.6285	-3.1877	13.9358	2.633	4.534	0.000
408	13.8894	12.5173	12.0461	12.6063	-3.1877	13.9134	3.717	3.698	0.000
409	13.9137	12.5140	12.0804	12.6298	-3.1877	13.9367	4.547	2.610	0.000
410	13.9521	12.4814	12.0555	12.6692	-3.1877	13.9718	5.068	1.344	0.000
411	13.9620	12.4021	12.0282	12.6785	-3.1877	13.9787	5.243	0.014	0.000
412	13.8509	12.6326	12.3663	12.5929	-3.1877	13.8896	4.493	-0.012	0.000
413	13.8305	12.7125	12.3749	12.5655	-3.1877	13.8763	4.337	-1.174	0.000
414	13.7820	12.7968	12.3009	12.5394	-3.1877	13.8376	3.885	-2.257	0.000
415	13.7607	12.8117	12.3128	12.5394	-3.1877	13.8207	3.169	-3.185	0.000
416	13.7832	12.8044	12.2833	12.5411	-3.1877	13.8388	2.236	-3.897	0.000
417	13.8315	12.6954	12.2257	12.5572	-3.1877	13.8721	1.152	-4.343	0.000
418	13.8525	12.6235	12.2759	12.5881	-3.1877	13.8882	-0.012	-4.493	0.000
419	13.8305	12.7318	12.2738	12.5608	-3.1877	13.8748	-1.174	-4.337	0.000
420	13.7820	12.7819	12.3145	12.5180	-3.1877	13.8367	-2.257	-3.885	0.000
421	13.7607	12.8015	12.3265	12.5137	-3.1877	13.8202	-3.185	-3.169	0.000
422	13.7832	12.8159	12.3004	12.5394	-3.1877	13.8403	-3.897	-2.236	0.000
423	13.8315	12.7271	12.2842	12.5649	-3.1877	13.8757	-4.343	-1.152	0.000
424	13.8525	12.6463	12.3031	12.5963	-3.1877	13.8901	-4.493	0.012	0.000
425	13.8305	12.6828	12.2883	12.5748	-3.1877	13.8718	-4.337	1.174	0.000
426	13.7820	12.7713	12.2480	12.5403	-3.1877	13.8339	-3.885	2.257	0.000
427	13.7607	12.8144	12.3150	12.5235	-3.1877	13.8211	-3.169	3.185	0.000
428	13.7832	12.7929	12.2929	12.5205	-3.1877	13.8380	-2.236	3.897	0.000
429	13.8315	12.7104	12.1941	12.5560	-3.1877	13.8724	-1.152	4.343	0.000
430	13.8525	12.6232	12.2390	12.5882	-3.1877	13.8873	0.012	4.493	0.000
431	13.8305	12.7282	12.2745	12.5713	-3.1877	13.8746	1.174	4.337	0.000
432	13.7820	12.8144	12.1690	12.5319	-3.1877	13.8359	2.257	3.885	0.000
433	13.7607	12.8143	12.1291	12.5051	-3.1877	13.8163	3.185	3.169	0.000
434	13.7832	12.7945	12.2445	12.5145	-3.1877	13.8369	3.897	2.236	0.000
435	13.8315	12.7204	12.2480	12.5681	-3.1877	13.8743	4.343	1.152	0.000
436	13.8509	12.6426	12.2416	12.5964	-3.1877	13.8869	4.493	0.012	0.000
437	13.7065	12.9185	12.6399	12.5075	-3.1877	13.8029	3.743	-0.010	0.000
438	13.6879	13.0151	12.6461	12.5186	-3.1877	13.8029	3.613	-0.978	0.000
439	13.5974	13.0726	12.5555	12.4575	-3.1877	13.7402	3.237	-1.880	0.000
440	13.5254	13.0665	12.5238	12.3654	-3.1877	13.6859	2.640	-2.654	0.000
441	13.6009	13.0657	12.5555	12.4021	-3.1877	13.7413	1.863	-3.247	0.000
442	13.6888	12.9920	12.6091	12.4635	-3.1877	13.7975	0.959	-3.618	0.000
443	13.7089	12.9494	12.6243	12.4827	-3.1877	13.8080	-0.010	-3.743	0.000
444	13.6879	12.9983	12.5777	12.4817	-3.1877	13.7957	-0.978	-3.613	0.000
445	13.5974	13.0412	12.6088	12.4235	-3.1877	13.7374	-1.880	-3.237	0.000
446	13.5254	13.0933	12.6273	12.3926	-3.1877	13.7004	-2.654	-2.640	0.000
447	13.6009	13.0825	12.5986	12.4402	-3.1877	13.7478	-3.247	-1.863	0.000
448	13.6888	12.9783	12.6532	12.5071	-3.1877	13.7984	-3.618	-0.959	0.000
449	13.7089	12.8935	12.6159	12.5126	-3.1877	13.8001	-3.743	0.010	0.000
450	13.6879	12.9305	12.5505	12.4696	-3.1877	13.7840	-3.613	0.978	0.000
451	13.5974	13.0444	12.5609	12.4516	-3.1877	13.7347	-3.237	1.880	0.000
452	13.5254	13.0783	12.5662	12.4080	-3.1877	13.6919	-2.640	2.654	0.000
453	13.6009	13.0557	12.5961	12.4436	-3.1877	13.7420	-1.863	3.247	0.000
454	13.6888	13.0172	12.5726	12.5049	-3.1877	13.7993	-0.959	3.618	0.000
455	13.7089	12.9489	12.5763	12.5096	-3.1877	13.8049	0.010	3.743	0.000
456	13.6879	12.9971	12.5943	12.5088	-3.1877	13.7966	0.978	3.613	0.000
457	13.5974	13.0809	12.5431	12.4332	-3.1877	13.7412	1.880	3.237	0.000
458	13.5254	13.0833	12.5310	12.3647	-3.1877	13.6906	2.654	2.640	0.000
459	13.6009	13.0494	12.5626	12.4034	-3.1877	13.7384	3.247	1.863	0.000

460	13.6888	12.9754	12.5559	12.4567	-3.1877	13.7916	3.618	0.959	0.000
461	13.7065	12.9186	12.5698	12.4916	-3.1877	13.7985	3.743	0.010	0.000
462	13.6100	13.0394	12.6873	12.4574	-3.1877	13.7525	3.008	-0.008	0.000
463	13.5901	13.1392	12.6999	12.5121	-3.1877	13.7612	2.904	-0.786	0.000
464	13.4569	13.1842	12.6710	12.4322	-3.1877	13.6867	2.601	-1.511	0.000
465	13.3299	13.1607	12.6425	12.2323	-3.1877	13.6047	2.122	-2.133	0.000
466	13.4631	13.1637	12.6874	12.3038	-3.1877	13.6857	1.497	-2.609	0.000
467	13.5912	13.1085	12.7788	12.4303	-3.1877	13.7624	0.771	-2.908	0.000
468	13.6131	13.0832	12.7656	12.4495	-3.1877	13.7706	-0.008	-3.008	0.000
469	13.5901	13.1070	12.7041	12.4542	-3.1877	13.7541	-0.786	-2.904	0.000
470	13.4569	13.1445	12.7088	12.3797	-3.1877	13.6785	-1.511	-2.601	0.000
471	13.3299	13.2186	12.7318	12.3113	-3.1877	13.6366	-2.133	-2.122	0.000
472	13.4631	13.2068	12.7151	12.3732	-3.1877	13.7019	-2.609	-1.497	0.000
473	13.5912	13.0862	12.8051	12.4934	-3.1877	13.7604	-2.908	-0.771	0.000
474	13.6131	12.9911	12.7808	12.4893	-3.1877	13.7548	-3.008	0.008	0.000
475	13.5901	13.0318	12.6918	12.4351	-3.1877	13.7371	-2.904	0.786	0.000
476	13.4569	13.1547	12.7135	12.4236	-3.1877	13.6820	-2.601	1.511	0.000
477	13.3299	13.1985	12.7068	12.3547	-3.1877	13.6259	-2.122	2.133	0.000
478	13.4631	13.1740	12.7551	12.4262	-3.1877	13.6960	-1.497	2.609	0.000
479	13.5912	13.1556	12.7237	12.4995	-3.1877	13.7680	-0.771	2.908	0.000
480	13.6131	13.0987	12.7200	12.4969	-3.1877	13.7696	0.008	3.008	0.000
481	13.5901	13.1062	12.7519	12.4841	-3.1877	13.7584	0.786	2.904	0.000
482	13.4569	13.1879	12.6941	12.3658	-3.1877	13.6902	1.511	2.601	0.000
483	13.3299	13.1908	12.6816	12.2941	-3.1877	13.6201	2.133	2.122	0.000
484	13.4631	13.1544	12.6952	12.3797	-3.1877	13.6837	2.609	1.497	0.000
485	13.5912	13.0943	12.6777	12.4118	-3.1877	13.7497	2.908	0.771	0.000
486	13.6100	13.0395	12.6780	12.4242	-3.1877	13.7517	3.008	0.008	0.000
487	-12.1546	12.1750	12.7295	9.2745	11.7365	12.8363	0.204	0.001	14.992
488	-12.2122	12.2101	12.7766	9.2745	11.7469	12.8809	0.197	0.053	14.992
489	-12.3439	12.2227	12.7727	9.2745	11.7091	12.8805	0.176	0.102	14.992
490	-12.4072	12.1385	12.7333	9.2745	11.5984	12.8316	0.144	0.145	14.992
491	-12.3411	12.1081	12.7452	9.2745	11.5232	12.8354	0.102	0.177	14.992
492	-12.2096	12.1428	12.7587	9.2745	11.6118	12.8529	0.052	0.197	14.992
493	-12.1416	12.1458	12.7349	9.2745	11.5802	12.8345	-0.001	0.204	14.992
494	-12.2122	12.2039	12.7214	9.2745	11.5051	12.8366	-0.053	0.197	14.992
495	-12.3439	12.1367	12.7364	9.2745	11.5266	12.8337	-0.102	0.176	14.992
496	-12.4072	12.1834	12.7686	9.2745	11.4781	12.8690	-0.145	0.144	14.992
497	-12.3411	12.1311	12.7971	9.2745	11.5017	12.8819	-0.177	0.102	14.992
498	-12.2096	11.9798	12.7760	9.2745	11.4720	12.8404	-0.197	0.052	14.992
499	-12.1416	12.0391	12.7579	9.2745	11.3771	12.8339	-0.204	-0.001	14.992
500	-12.2122	12.0258	12.7372	9.2745	11.3131	12.8144	-0.197	-0.053	14.992
501	-12.3439	12.0395	12.7531	9.2745	11.2574	12.8298	-0.176	-0.102	14.992
502	-12.4072	12.1315	12.7750	9.2745	11.3770	12.8639	-0.144	-0.145	14.992
503	-12.3411	12.0221	12.7057	9.2745	11.6223	12.7875	-0.102	-0.177	14.992
504	-12.2096	11.8811	12.7016	9.2745	11.6597	12.7627	-0.052	-0.197	14.992
505	-12.1416	11.9582	12.7492	9.2745	11.5178	12.8143	0.001	-0.204	14.992
506	-12.2122	11.9276	12.7225	9.2745	11.1848	12.7871	0.053	-0.197	14.992
507	-12.3439	12.0202	12.7055	9.2745	11.0517	12.7870	0.102	-0.176	14.992
508	-12.4072	11.9213	12.7217	9.2745	11.3969	12.7855	0.145	-0.144	14.992
509	-12.3411	12.0131	12.7503	9.2745	11.4670	12.8233	0.177	-0.102	14.992
510	-12.2096	12.1438	12.7450	9.2745	11.2950	12.8421	0.197	-0.052	14.992
511	-12.1546	12.1110	12.7259	9.2745	11.2963	12.8203	0.204	-0.001	14.992
512	-4.9434	12.4992	12.7759	9.2745	11.7669	12.9602	1.871	0.005	14.158
513	-5.2149	12.4674	12.7994	9.2745	11.6525	12.9654	1.806	0.489	14.158
514	-6.4661	12.4377	12.7915	9.2745	11.6730	12.9507	1.618	0.940	14.158
515	-12.4072	12.3833	12.7884	9.2745	11.6696	12.9325	1.319	1.326	14.158
516	-6.4507	12.3912	12.7979	9.2745	11.6674	12.9415	0.931	1.623	14.158
517	-5.1970	12.3958	12.7988	9.2745	11.6776	12.9435	0.479	1.808	14.158
518	-4.8968	12.4116	12.7680	9.2745	11.5745	12.9264	-0.005	1.871	14.158
519	-5.2149	12.4795	12.7621	9.2745	11.5785	12.9444	-0.489	1.806	14.158
520	-6.4661	12.4139	12.7811	9.2745	11.7021	12.9362	-0.940	1.618	14.158
521	-12.4072	12.3908	12.7761	9.2745	11.5918	12.9258	-1.326	1.319	14.158
522	-6.4507	12.4127	12.8071	9.2745	11.6134	12.9543	-1.623	0.931	14.158
523	-5.1970	12.4033	12.7991	9.2745	11.6362	12.9458	-1.808	0.479	14.158

524	-4.8968	12.4151	12.7799	9.2745	11.4627	12.9358	-1.871	-0.005	14.158
525	-5.2149	12.3601	12.7788	9.2745	11.5581	12.9191	-1.806	-0.489	14.158
526	-6.4661	12.3298	12.8095	9.2745	11.5707	12.9338	-1.618	-0.940	14.158
527	-12.4072	12.4101	12.7988	9.2745	11.5557	12.9476	-1.319	-1.326	14.158
528	-6.4507	12.3525	12.7603	9.2745	11.6795	12.9036	-0.931	-1.623	14.158
529	-5.1970	12.2973	12.7811	9.2745	11.7281	12.9044	-0.479	-1.808	14.158
530	-4.8968	12.3702	12.7698	9.2745	11.6905	12.9155	0.005	-1.871	14.158
531	-5.2149	12.3654	12.7529	9.2745	11.6028	12.9020	0.489	-1.806	14.158
532	-6.4661	12.4282	12.7582	9.2745	11.5091	12.9248	0.940	-1.618	14.158
533	-12.4072	12.4146	12.8023	9.2745	11.5760	12.9514	1.326	-1.319	14.158
534	-6.4507	12.3863	12.8302	9.2745	11.6487	12.9637	1.623	-0.931	14.158
535	-5.1970	12.4664	12.7963	9.2745	11.6659	12.9630	1.808	-0.479	14.158
536	-4.9434	12.4909	12.7746	9.2745	11.6838	12.9565	1.871	-0.005	14.158
537	3.1523	12.6113	12.5901	9.2745	11.6691	12.9018	2.360	0.006	13.325
538	2.8739	12.5560	12.6242	9.2745	11.4931	12.8925	2.278	0.617	13.325
539	1.5522	12.5458	12.6404	9.2745	11.6331	12.8967	2.041	1.185	13.325
540	-12.4072	12.5407	12.6673	9.2745	11.7302	12.9096	1.664	1.673	13.325
541	1.5721	12.5635	12.6618	9.2745	11.7158	12.9165	1.175	2.047	13.325
542	2.8920	12.5486	12.6255	9.2745	11.6261	12.8898	0.605	2.281	13.325
543	3.2002	12.5514	12.5903	9.2745	11.4529	12.8723	-0.006	2.360	13.325
544	2.8739	12.5903	12.6114	9.2745	11.4541	12.9020	-0.617	2.278	13.325
545	1.5522	12.5368	12.6523	9.2745	11.5666	12.8994	-1.185	2.041	13.325
546	-12.4072	12.4992	12.6364	9.2745	11.5941	12.8742	-1.673	1.664	13.325
547	1.5721	12.5255	12.6399	9.2745	11.6085	12.8875	-2.047	1.175	13.325
548	2.8920	12.5959	12.6341	9.2745	11.6564	12.9164	-2.281	0.605	13.325
549	3.2002	12.6290	12.5995	9.2745	11.5916	12.9155	-2.360	-0.006	13.325
550	2.8739	12.5428	12.6446	9.2745	11.5920	12.8977	-2.278	-0.617	13.325
551	1.5522	12.4870	12.7154	9.2745	11.6594	12.9171	-2.041	-1.185	13.325
552	-12.4072	12.5267	12.6603	9.2745	11.6834	12.8996	-1.664	-1.673	13.325
553	1.5721	12.4999	12.6223	9.2745	11.6800	12.8664	-1.175	-2.047	13.325
554	2.8920	12.5242	12.6326	9.2745	11.6353	12.8828	-0.605	-2.281	13.325
555	3.2002	12.6039	12.5794	9.2745	11.6541	12.8929	0.006	-2.360	13.325
556	2.8739	12.5660	12.6205	9.2745	11.6704	12.8951	0.617	-2.278	13.325
557	1.5522	12.5353	12.6549	9.2745	11.5887	12.9002	1.185	-2.041	13.325
558	-12.4072	12.5333	12.6859	9.2745	11.6648	12.9173	1.673	-1.664	13.325
559	1.5721	12.5370	12.6996	9.2745	11.7639	12.9269	2.047	-1.175	13.325
560	2.8920	12.6016	12.6290	9.2745	11.7481	12.9165	2.281	-0.605	13.325
561	3.1523	12.6223	12.5903	9.2745	11.7222	12.9077	2.360	-0.006	13.325
562	6.3886	12.6700	11.9258	9.2745	11.4159	12.7420	2.500	0.007	12.492
563	6.2199	12.6377	12.0064	9.2745	11.3554	12.7289	2.413	0.653	12.492
564	5.5805	12.6319	12.0236	9.2745	11.4953	12.7276	2.162	1.256	12.492
565	3.8891	12.6328	12.0920	9.2745	11.5569	12.7427	1.763	1.772	12.492
566	5.6026	12.6292	12.1289	9.2745	11.4685	12.7484	1.244	2.168	12.492
567	6.2298	12.6309	12.0179	9.2745	11.4099	12.7256	0.641	2.416	12.492
568	6.3887	12.6098	12.0034	9.2745	11.4199	12.7059	-0.007	2.500	12.492
569	6.2199	12.6121	12.0511	9.2745	11.3356	12.7176	-0.653	2.413	12.492
570	5.5805	12.6156	12.1388	9.2745	11.2065	12.7406	-1.256	2.162	12.492
571	3.8891	12.5692	12.1775	9.2745	11.3769	12.7171	-1.772	1.763	12.492
572	5.6026	12.5695	12.0883	9.2745	11.4663	12.6934	-2.168	1.244	12.492
573	6.2298	12.6343	12.0529	9.2745	11.5351	12.7355	-2.416	0.641	12.492
574	6.3887	12.6401	11.9716	9.2745	11.5356	12.7245	-2.500	-0.007	12.492
575	6.2199	12.6020	12.0740	9.2745	11.3411	12.7148	-2.413	-0.653	12.492
576	5.5805	12.5821	12.2285	9.2745	11.4379	12.7413	-2.162	-1.256	12.492
577	3.8891	12.5915	12.1497	9.2745	11.5492	12.7255	-1.763	-1.772	12.492
578	5.6026	12.5973	12.0587	9.2745	11.4838	12.7076	-1.244	-2.168	12.492
579	6.2298	12.6134	11.9530	9.2745	11.3106	12.6992	-0.641	-2.416	12.492
580	6.3887	12.6493	11.9107	9.2745	11.3617	12.7221	0.007	-2.500	12.492
581	6.2199	12.6237	12.0874	9.2745	11.3937	12.7346	0.653	-2.413	12.492
582	5.5805	12.5331	12.1714	9.2745	11.4057	12.6899	1.256	-2.162	12.492
583	3.8891	12.4931	12.1157	9.2745	11.5812	12.6452	1.772	-1.763	12.492
584	5.6026	12.6033	12.0448	9.2745	11.6306	12.7093	2.168	-1.244	12.492
585	6.2298	12.6622	11.9088	9.2745	11.5949	12.7327	2.416	-0.641	12.492
586	6.3886	12.6602	11.8328	9.2745	11.5616	12.7204	2.500	-0.007	12.492
587	6.3661	12.7347	11.4412	9.2745	11.4731	12.7562	2.354	0.006	11.658

588	6.1995	12.7094	11.5675	9.2745	11.3501	12.7396	2.272	0.615	11.658
589	5.5692	12.6948	11.5085	9.2745	11.2590	12.7222	2.036	1.182	11.658
590	3.8930	12.6825	11.4111	9.2745	11.3607	12.7052	1.660	1.669	11.658
591	5.5911	12.6523	11.6781	9.2745	11.3154	12.6961	1.172	2.042	11.658
592	6.2091	12.6795	11.6140	9.2745	11.4125	12.7154	0.603	2.275	11.658
593	6.3661	12.7021	11.4888	9.2745	11.5441	12.7279	−0.006	2.354	11.658
594	6.1995	12.6848	11.6830	9.2745	11.4382	12.7260	−0.615	2.272	11.658
595	5.5692	12.6796	11.5751	9.2745	11.3346	12.7125	−1.182	2.036	11.658
596	3.8930	12.6667	11.5176	9.2745	11.4801	12.6964	−1.669	1.660	11.658
597	5.5911	12.6672	11.6612	9.2745	11.5310	12.7081	−2.042	1.172	11.658
598	6.2091	12.6759	11.5131	9.2745	11.4960	12.7047	−2.275	0.603	11.658
599	6.3661	12.6833	11.5453	9.2745	11.4500	12.7138	−2.354	−0.006	11.658
600	6.1995	12.6795	11.6418	9.2745	11.2686	12.7176	−2.272	−0.615	11.658
601	5.5692	12.6572	11.4639	9.2745	11.2262	12.6842	−2.036	−1.182	11.658
602	3.8930	12.6782	11.5040	9.2745	11.3893	12.7063	−1.660	−1.669	11.658
603	5.5911	12.6847	11.4456	9.2745	11.4102	12.7091	−1.172	−2.042	11.658
604	6.2091	12.6674	11.6318	9.2745	11.4149	12.7057	−0.603	−2.275	11.658
605	6.3661	12.6957	11.7149	9.2745	11.5554	12.7389	0.006	−2.354	11.658
606	6.1995	12.6924	11.6552	9.2745	11.5257	12.7305	0.615	−2.272	11.658
607	5.5692	12.6749	11.5259	9.2745	11.3317	12.7047	1.182	−2.036	11.658
608	3.8930	12.6821	11.3594	9.2745	11.4743	12.7022	1.669	−1.660	11.658
609	5.5911	12.6995	11.5285	9.2745	11.4764	12.7279	2.042	−1.172	11.658
610	6.2091	12.7210	11.5023	9.2745	11.4066	12.7465	2.275	−0.603	11.658
611	6.3661	12.7241	11.2333	9.2745	11.5087	12.7379	2.354	−0.006	11.658
612	4.0688	12.4164	11.5680	9.2745	11.2576	12.4740	1.856	0.005	10.825
613	4.0468	12.3858	11.7611	9.2745	11.1683	12.4783	1.791	0.485	10.825
614	3.7434	12.4062	11.7607	9.2745	10.9968	12.4948	1.605	0.932	10.825
615	2.3770	12.3938	11.6434	9.2745	11.1125	12.4649	1.309	1.316	10.825
616	3.7605	12.3392	11.6940	9.2745	11.1031	12.4278	0.924	1.610	10.825
617	4.0478	12.3823	11.6971	9.2745	11.2166	12.4638	0.476	1.794	10.825
618	4.0714	12.4479	11.5889	9.2745	11.3316	12.5042	−0.005	1.856	10.825
619	4.0468	12.4231	11.6191	9.2745	11.1292	12.4864	−0.485	1.791	10.825
620	3.7434	12.3777	11.6210	9.2745	10.9714	12.4478	−0.932	1.605	10.825
621	2.3770	12.3966	11.6913	9.2745	11.3214	12.4747	−1.316	1.309	10.825
622	3.7605	12.3943	11.7885	9.2745	11.2971	12.4905	−1.610	0.924	10.825
623	4.0478	12.4013	11.7749	9.2745	11.3054	12.4935	−1.794	0.476	10.825
624	4.0714	12.4552	11.7929	9.2745	11.3076	12.5407	−1.856	−0.005	10.825
625	4.0468	12.4263	11.6904	9.2745	11.0440	12.4995	−1.791	−0.485	10.825
626	3.7434	12.3786	11.5198	9.2745	10.9490	12.4349	−1.605	−0.932	10.825
627	2.3770	12.4079	11.5965	9.2745	11.1215	12.4703	−1.309	−1.316	10.825
628	3.7605	12.4041	11.6509	9.2745	11.2157	12.4747	−0.924	−1.610	10.825
629	4.0478	12.3976	11.7125	9.2745	11.2569	12.4792	−0.476	−1.794	10.825
630	4.0714	12.4531	11.7629	9.2745	11.4044	12.5338	0.005	−1.856	10.825
631	4.0468	12.4269	11.7489	9.2745	11.4061	12.5097	0.485	−1.791	10.825
632	3.7434	12.4367	11.6963	9.2745	11.0937	12.5092	0.932	−1.605	10.825
633	2.3770	12.4857	11.5769	9.2745	11.1291	12.5362	1.316	−1.309	10.825
634	3.7605	12.4352	11.7249	9.2745	11.2096	12.5125	1.610	−0.924	10.825
635	4.0478	12.4140	11.6943	9.2745	10.8742	12.4898	1.794	−0.476	10.825
636	4.0688	12.4239	11.5311	9.2745	11.0552	12.4762	1.856	−0.005	10.825
637	−6.7326	11.6440	11.7190	9.2745	10.0491	11.9841	0.204	0.001	10.008
638	−6.7326	11.6646	11.8615	9.2745	10.5334	12.0752	0.197	0.053	10.008
639	−6.7326	11.8191	11.7937	9.2745	10.6285	12.1076	0.176	0.102	10.008
640	−6.7326	11.7489	11.7655	9.2745	10.2221	12.0583	0.144	0.145	10.008
641	−6.7326	11.5853	11.7616	9.2745	10.1942	11.9833	0.102	0.177	10.008
642	−6.7326	11.6574	11.7855	9.2745	10.6872	12.0272	0.052	0.197	10.008
643	−6.7326	11.6824	11.7554	9.2745	10.8418	12.0215	−0.001	0.204	10.008
644	−6.7326	11.7351	11.6059	9.2745	10.5221	11.9763	−0.053	0.197	10.008
645	−6.7326	11.6976	11.7337	9.2745	9.7546	12.0171	−0.102	0.176	10.008
646	−6.7326	11.5327	11.8865	9.2745	10.0432	12.0457	−0.145	0.144	10.008
647	−6.7326	11.4960	11.8678	9.2745	10.2823	12.0216	−0.177	0.102	10.008
648	−6.7326	11.6969	11.9256	9.2745	11.1030	12.1272	−0.197	0.052	10.008
649	−6.7326	11.7639	11.9120	9.2745	11.0222	12.1453	−0.204	−0.001	10.008
650	−6.7326	11.6613	11.6924	9.2745	10.5819	11.9782	−0.197	−0.053	10.008
651	−6.7326	11.6890	11.6309	9.2745	10.5697	11.9620	−0.176	−0.102	10.008

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653	-6.7326	11.7106	11.8229	9.2745	10.5257	12.0714	-0.102	-0.177	10.008
654	-6.7326	11.7459	11.7307	9.2745	10.4460	12.0394	-0.052	-0.197	10.008
655	-6.7326	11.7493	11.6936	9.2745	10.3499	12.0234	0.001	-0.204	10.008
656	-6.7326	11.6620	11.7919	9.2745	10.8380	12.0328	0.053	-0.197	10.008
657	-6.7326	11.5807	11.8464	9.2745	10.8775	12.0346	0.102	-0.176	10.008
658	-6.7326	11.6961	11.7859	9.2745	10.2510	12.0444	0.145	-0.144	10.008
659	-6.7326	11.7011	11.8104	9.2745	10.5967	12.0602	0.177	-0.102	10.008
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612	636	661	637

A.7 TECPLOT Output Graphs

Figure A2 is a black and white plot of the display of the results of the SHADOWV2 sample run contained in sample.tec. The colors of the actual TECPLOT display are labeled on figure A2, and the structure has been rotated so that it can be viewed more clearly. The numbers along the color scale on the figure are the the base 10 logarithms of atomic oxygen flux (number/s/cm^2). Examination of the figure shows that the highest flux is along the outside edge of the disk due to direct flux from near the ram direction. The square also receives high flux, mostly reflected from the disk. (Remember that the active side of the square is facing down.) The sphere near the tangent point with the square receives most of its flux from diffuse reflection from the square and multiple reflections between the square and the sphere. The bottom of the sphere and the top of the cone are well shielded from atomic oxygen flux. The bottom of the cone receives flux reflected from the plane. The cylinder receives most of its flux from specular and diffuse reflection from the disk. The variation in fluxes over positions which would be expected to receive the same flux is due to the statistical nature of the Monte Carlo simulation. This variation can be reduced by increasing the number of rays traced in the simulation.

Figure A3 is a graph that has been extracted from the plot shown in figure A2. A line has been drawn diagonally along the surface of the square from corner to corner, and the graph generated shows the base 10 log of the atomic oxygen flux along the line as a function of distance in the x direction. Note the dip in the center due to shading.

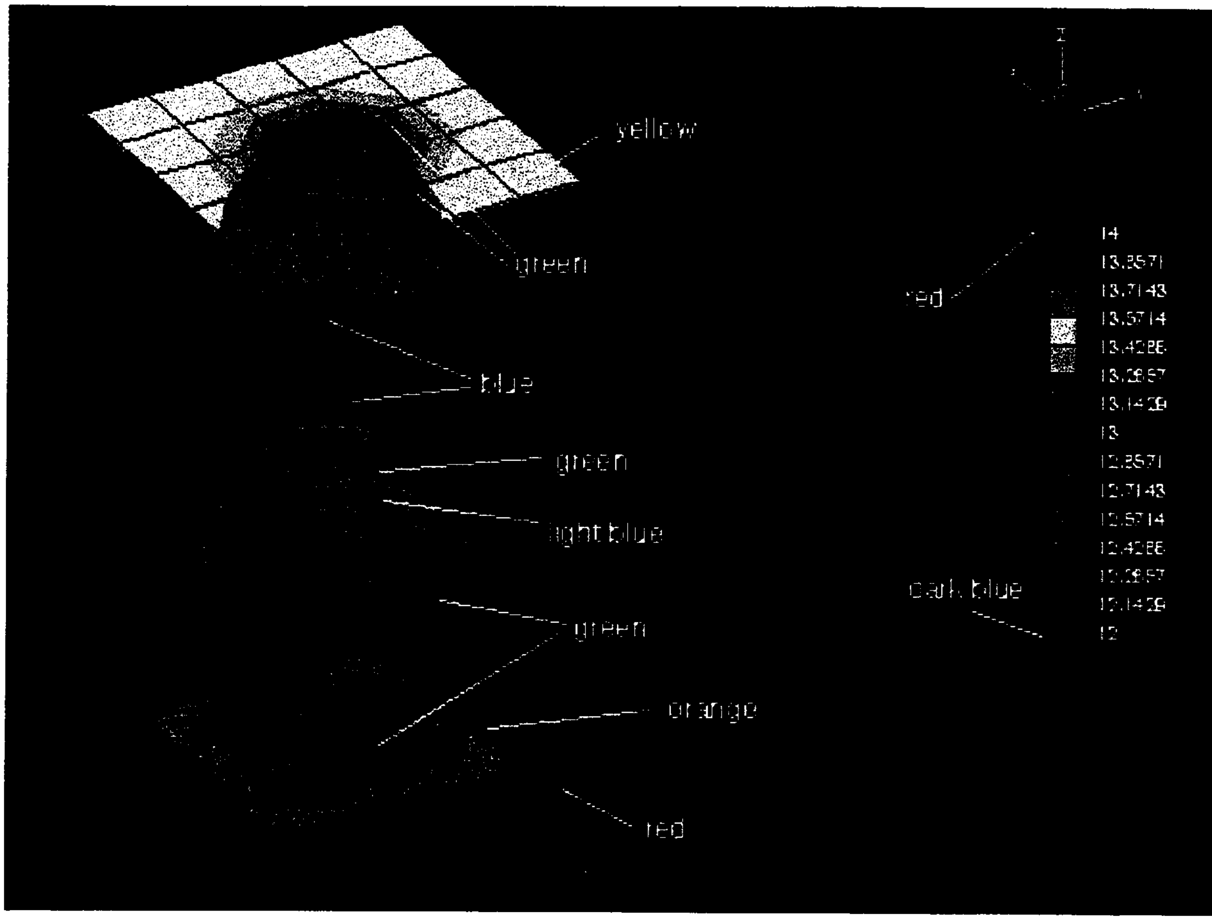

Figure A2. Black and White Plot of the Sample TECPLOT File Generated by SHADOW

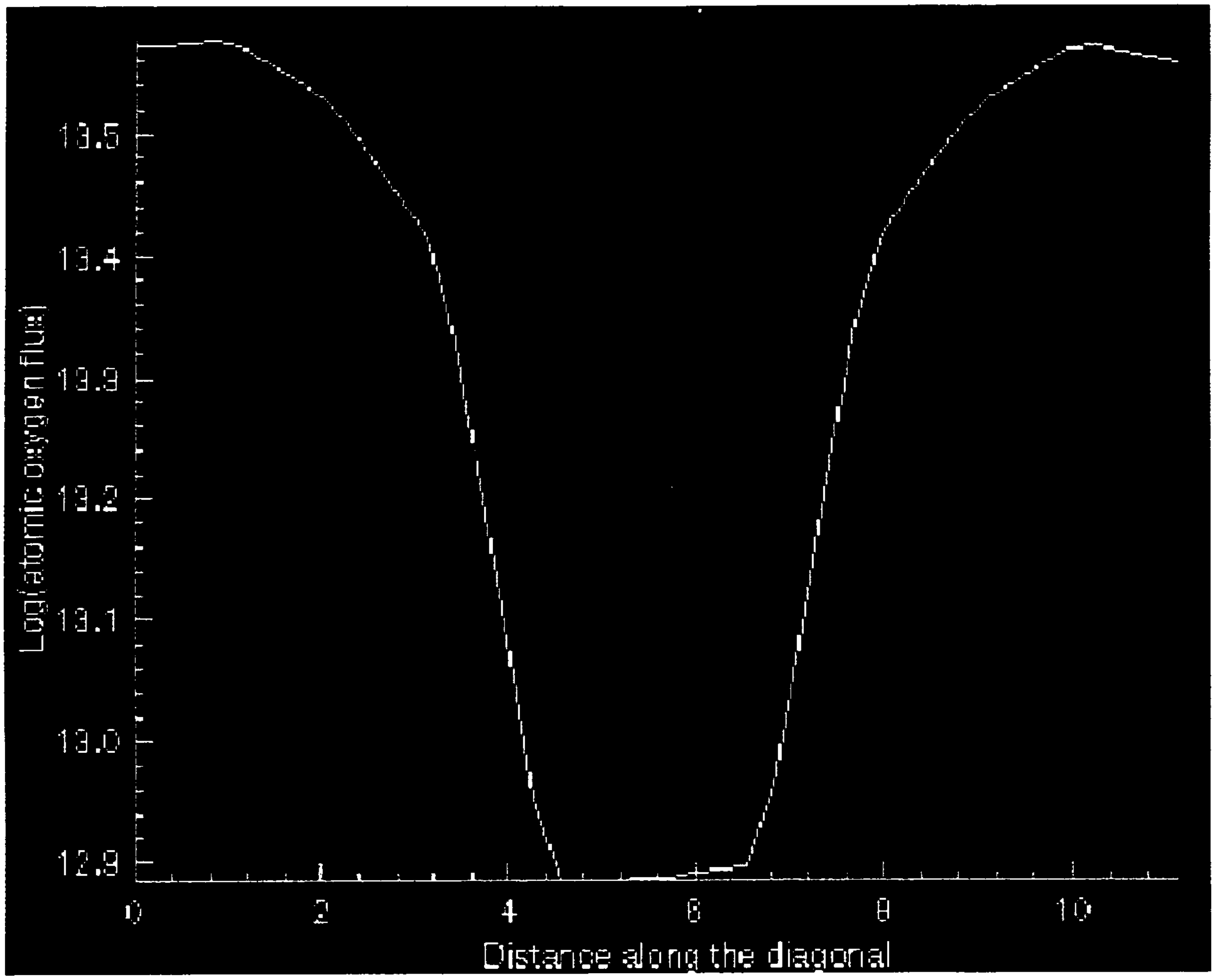

Figure A3. An X-Y Graph of the Base 10 log of the Atomic Oxygen Flux as a Function of Distance in the X Direction, Along the Diagonal Line of the Square Shown in Figure A2

APPENDIX B: FORMAT OF OUTPUT FILES FOR TECPLOT

B.1 TECPLOT Output File From SHADOWV2

SHADOWV2 produces an ASCII file of the nodes, fluxes, and connectivity matrix formatted for processing by PREPLOT to create a binary input file for TECPLOT. TECPLOT displays this file as a plot of the object with the fluxes color coded on the surfaces. This file is named TAPE7 and is opened in SHADOWV2 (subroutine CONNEC) as STATUS = 'UNKNOWN', FORM = 'FORMATTED'. STATUS = 'UNKNOWN' causes any existing version of TAPE7 to be overwritten. The last line of the batch file **run.shadowv2** gives the file TAPE7 a new name. Therefore, users should take care to change the name of the file in **run.shadowv2** if they wish to preserve results of previous SHADOWV2 runs.

Record E1 Format (1X,'TITLE="',A,'"')

Entry	Columns	Type	Variable
Description of geometry from record B1	9-69	character	HEADER

Record E2 Format (' VARIABLES=NODE,PRIM,SPEC,DIFF,RECOMB,REACT, TOTAL,X,Y,Z')

This record provides variable names for the columns of data in record E3.

Record E3 Format (' ZONE T="SURF 1",I=',I4,',J=',I4,'F=FEPOINT')

Entry	Columns	Type	Variable
Number of nodes (points) on the surfaces of the structure.	20-23	integer	NODETOT
Number of elements in the connectivity matrix.	27-30	integer	NCON

Record E4 Format (I6,6F10.4,3F10.3)

This record is repeated NODETOT times, once for the data at each node.

Entry	Columns	Type	Variable
Node number.	1-6	integer	L
Log 10 primary AO flux (number/cm^2/s) at node.	7-16	real	FLUX(1,L)
Log 10 specular reflected AO flux (number/cm^2/s) at node.	17-26	real	FLUX(2,L)
Log 10 diffusely reflected AO flux (number/cm^2/s) at node.	27-36	real	FLUX(3,L)
Log 10 recombination AO flux (number/cm^2/s) at node.	37-46	real	FLUX(4,L)
Log 10 surface reaction AO flux (number/cm^2/s) at node.	47-56	real	FLUX(5,L)
Log 10 total = primary + specular reflected + diffusely reflected AO flux (number/cm^2/s) at node.	57-66	real	FLUX(6,L)
X coordinate of node	67-76	real	PTNODE(1,L)
Y coordinate of node	77-86	real	PTNODE(2,L)
Z coordinate of node	87-96	real	PTNODE(3,L)

Record E5 Format (4I10)

This record is repeated NCON times, once for each element of the connectivity matrix.

Entry	Columns	Type	Variable
The indices of the four nodes defining an element of the connectivity matrix. When the four nodes are connected in order, they form a quadrilateral (or a triangle if two adjacent points are identical).	1-10, 11-20, 21-30, 31-40	integer	ICONEC

B.2 TECPLOT Output Files from MDDB

TECPLOT Binary Output File From MDDB. MDDB produces a binary TECPLOT file whenever a TECPLOT display of the object is selected. This file is readable directly by the PC version of TECPLOT 5.0x without need for preprocessing by PREPLOT. The binary file is named MDDB.PLT and is opened in subroutine GENSURF with a FORTRAN open statement as unit 9, STATUS = 'UNKNOWN', FORM = 'BINARY'. STATUS = 'UNKNOWN' causes any existing version of MDDB.PLT to be overwritten. The new version of the file is written in subroutine CONNECM. Because the file is binary, its format is described by contents of individual words rather than by record content. Each word is considered to be a 32-bit real or integer value. When specific values are given in the table below, they are written to the binary file.

Number of words	Type	Contents
1	real	Version number of the input file = 5.0.
80	real	Description of geometry read in record B1 of section 2.2.1 blank padded to 80 characters. Each character is written to MDDB.PLT as the real value of its integer ASCII value.
1	real	Number of variables = 5.0 for which data is written to MDDB.PLT.
25	real	The 5-character names of the variables: 'NODE ', 'COLOR', 'X ', 'Y ', 'Z '. Each character is written to MDDB.PLT as the real value of its integer ASCII value.
1	real	Zone marker = 299.0.
10	real	Ten character zone name: 'SURFACES '. Each character is written to MDDB.PLT as the real value of its integer ASCII value.
1	real	Format of data = 3.0, which indicates FEPOINT.
1	real	Z plane value = 0.0.
1	real	Number of nodes NODETV.
1	real	Number of elements in connectivity matrix NCONV.
1	real	End of header marker = 357.0.
1	real	Zone marker = 299.0.
1	real	Number of repeat variables = 0.0.
5.0*NODETV	real	One word of data for each of five variable values for the NODETV nodes. Data are written in order as NODE1, COLOR1, X1, Y1, Z1 NODE2, COLOR2, X2, Y2, Z2 etc.
4.0*NCONV	integer	One word of data for each of the indices of the four points of the connectivity matrix for the NCONV elements. When the four nodes are connected in order, they form a quadrilateral (or a triangle if two adjacent points are identical).

TECPLOT ASCII Output File from MDDB. MDDB also produces an ASCII TECPLOT file whenever a TECPLOT display of the object is selected. This file is readable by PREPLOT which creates a binary file used by TECPLOT. The ASCII file is named MDDB.PRE and is opened in subroutine GENSURF with a FORTRAN open statement as unit 7, STATUS = 'UNKNOWN', FORM = 'FORMATTED'. STATUS = 'UNKNOWN' causes any existing version of MDDB.PRE to be overwritten. The new version of the file is written in subroutine CONNECM. The format of this file is described below. When specific values are given, they are written to the file.

Record F1 Format (1X,'TITLE="',A,'"')

Entry	Columns	Type	Variable
Description of geometry from record B1	9-69	character	HEADER

Record F2 Format (' VARIABLES=NODE,COLOR,X,Y,Z')
This record provides variable names for the columns of data in record F4.

Record F3 Format (' ZONE T="SURF 1",I=',I4,',J=',I4,'F=FEPOINT')

Entry	Columns	Type	Variable
Number of nodes (points) on the surfaces of the structure plus the surface normal direction arrows.	20-23	integer	NODETV
Number of elements in the connectivity matrix.	27-30	integer	NCONV

Record F4 Format (I6,F10.4,3F10.3)I6,F10.4,3F10.3)') L,COLOR,PT

This record is repeated NODETV times to generate all of the surfaces and surface normal direction arrows.

Entry	Columns	Type	Variable
Node number.	1-6	integer	L
Color of node.	7-16	real	COLOR
X coordinate of node	17-26	real	PT(1) or ARROW(1,J)
Y coordinate of node	27-36	real	PT(2) or ARROW(2,J)
Z coordinate of node	37-46	real	PT(3) or ARROW(3,J)

Record F5 Format (4I10)

This record is repeated NCONV times, once for each element of the connectivity matrix.

Entry	Columns	Type	Variable
The indices of the four nodes defining an element of the connectivity matrix. When the four nodes are connected in order, they form a quadrilateral (or a triangle if two adjacent points are identical).	1-10, 11-20, 21-30, 31-40	integer	ICONEC

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R. J. Bourassa
J. R. Gillis
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